



Mobility Demonstrator

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Objective



- Presentation of the Mobility Demonstrator effort which exercised a “paradigm shift” in TARDEC Mobility's traditional methodology / thinking regarding combat vehicle mobility design.
- Exercising of atypical methods to stimulate creativity.
- Focus on innovative / creative thought towards mobility systems.
- Perform a subsystem-by-subsystem evaluation of the art of the possible.



Engineers Gone Wild !

Exercise I



- TARDEC Engineers sequestered and tasked to concept a new vehicle.
- Requirements - Futuristic, highly mobile, 40 ton weight.
- Concepts to be grounded in some reality, albeit innovative to the point of science-fiction.
- To be “safe”, engineers developed short , medium, and long-range concepts.
- Engineers found lack of defined requirements “stressful”.



*Wheeled
Conventional Design*



*Quad Tracked
Vehicle*



*Modular/Detachable Center
Pod & Scouts Vehicle*



*Highly Articulated
Wheeled Vehicle*

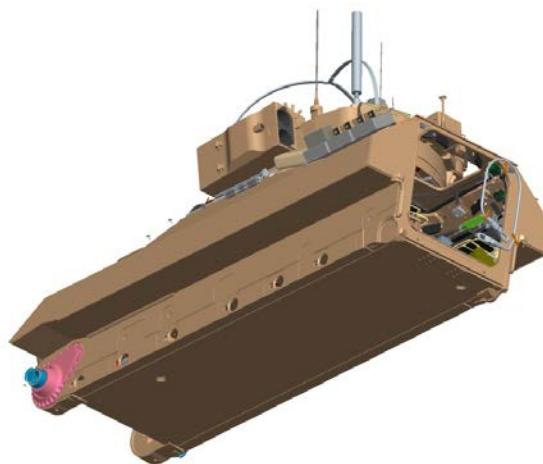


Wheels on a Bradley !

Exercise II



- Mechanical Track Drive / Electric Wheeled Drive Approach
- Modular Mechanical Track Running Gear
- Modular Electric In-Hub Motor Wheels with External Hydraulic Suspension Unit (HSU) Running Gear System
- Both systems fit in same sponson cavity location.



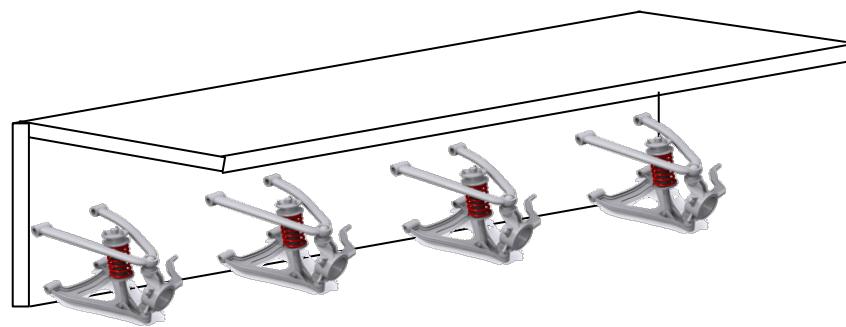
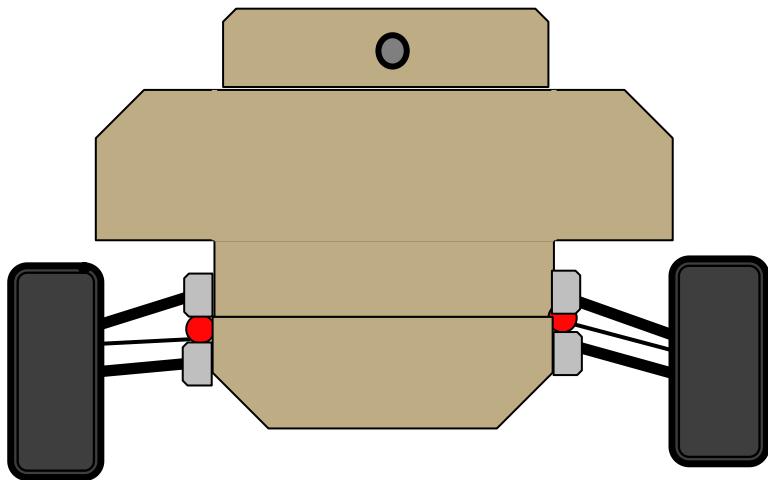


Tracked Modular Suspension





Wheeled Modular Suspension

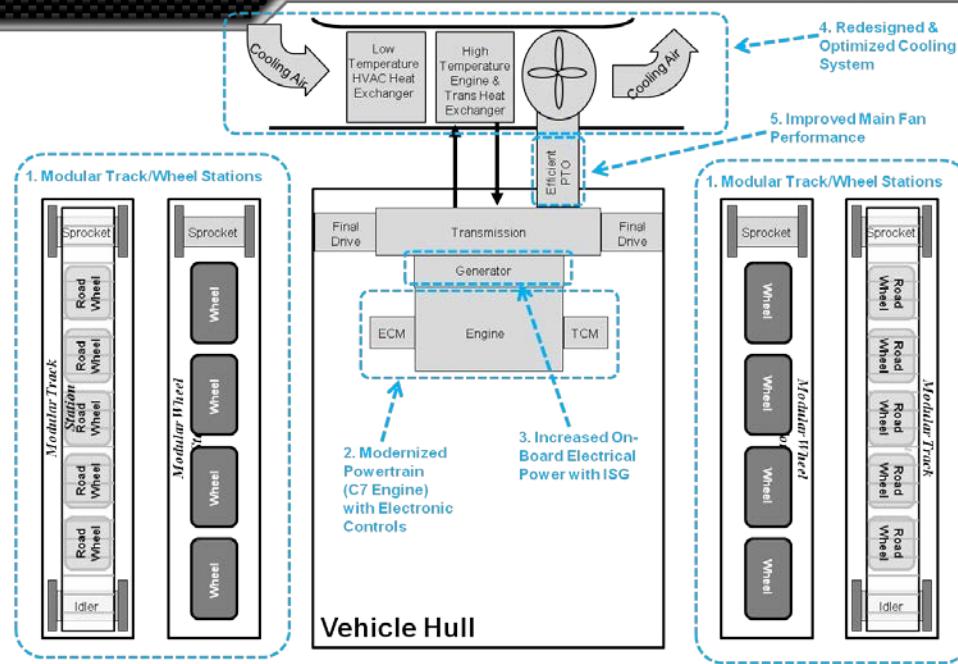




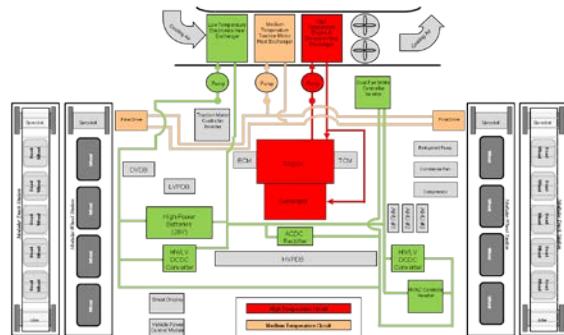
Propulsion Architecture



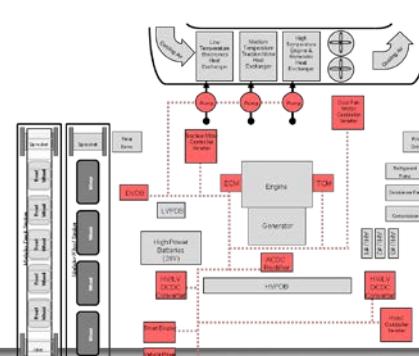
Mechanical Track Drive / Electric Wheel Drive Propulsion System



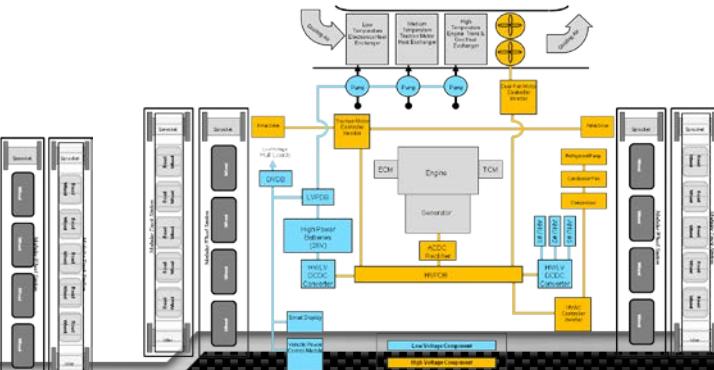
Electrical Power



Thermal Management

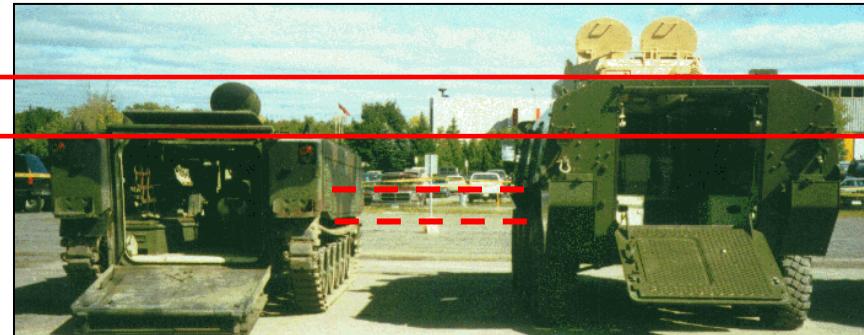


Communications and Control

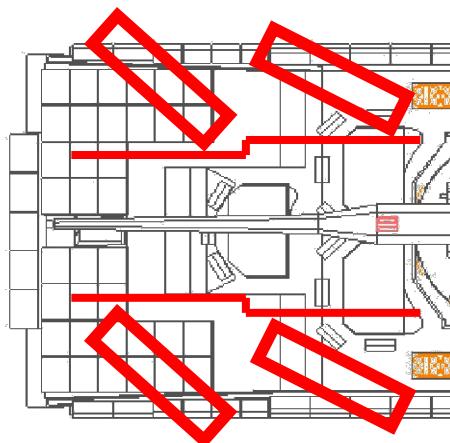




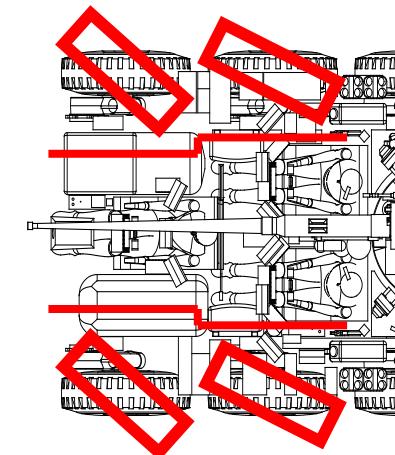
Sponsons



Vehicle Heights



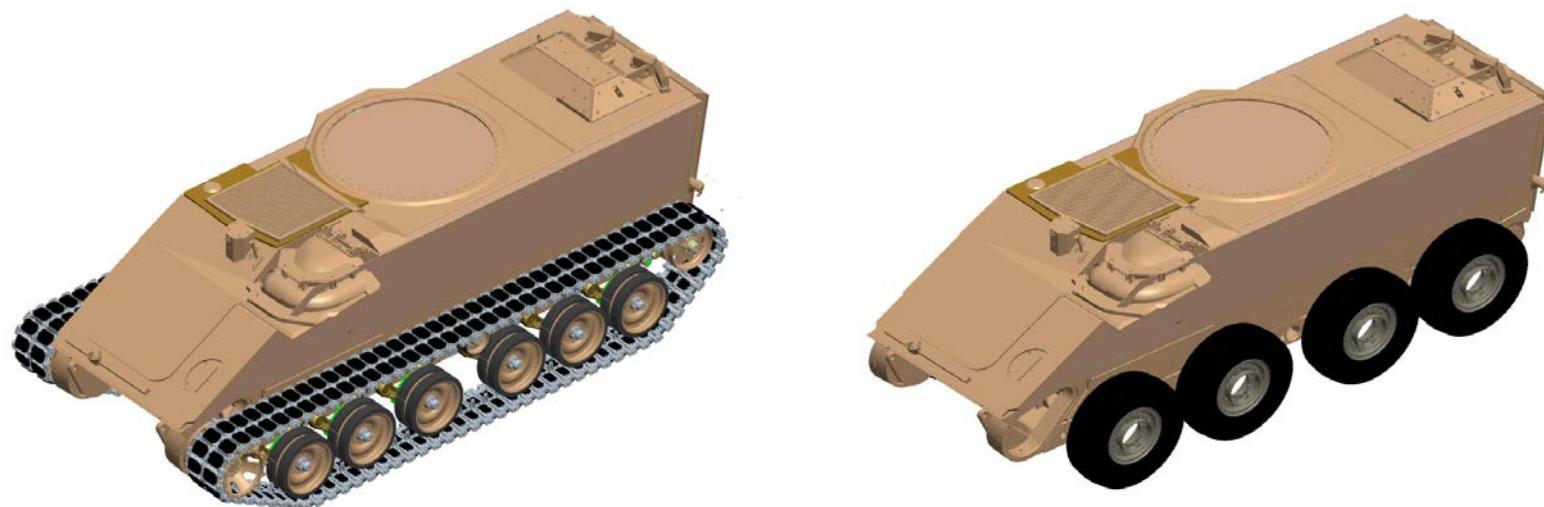
Ackerman Steering Volume Requirements



Converting tracked vehicle to wheels requires raising vehicle and / or widening vehicle wheelbase



Bradley with Sponsons Removed





- 17-19 December 2012 – TARDEC Innovation Event
- Purpose: To collaborate and develop new mobility and situational awareness ideas for combat tracked and wheeled vehicles using latest Mobility Demonstrator Guidance.
- Participants:
 - 4 Chief Warrant Officers from the U.S. Army Ordnance Center and School.
 - 11 College of Creative Studies Associate Professor and Students
 - 11 TARDEC Engineers
- Concept a theoretical “Mobility Demonstrator” military vehicle with flexible / reconfigurable running gear system capable of converting between tracks and wheel modes.
- Agnostic to either wheels or tracks during the assembly process.
- Focus on future commonality of mobility components and systems.
- Maximum 40 ton weight.
- Military environment.
- Be novel, creative, anything goes.



Tracked Military Vehicles





Wheeled Military Vehicles





Performance Comparisons



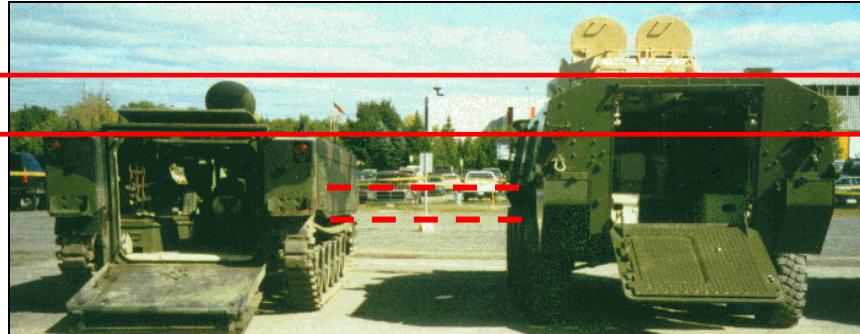
- Greater Vehicle Weights
- Faster Pavement Road Speed
- Lower Ground Pressure
- Greater Vertical Climb
- Greater Trench Crossing

Wheels	Tracks
	X
X	
	X
	X
	X



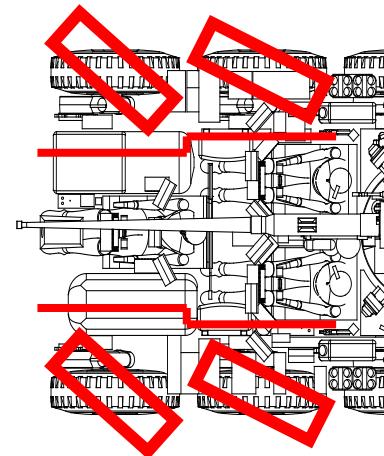
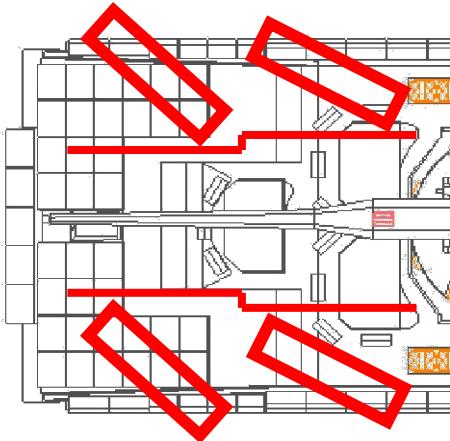
Chassis Considerations

Sponsons



Vehicle Heights

Ackerman Steering Volume Requirements

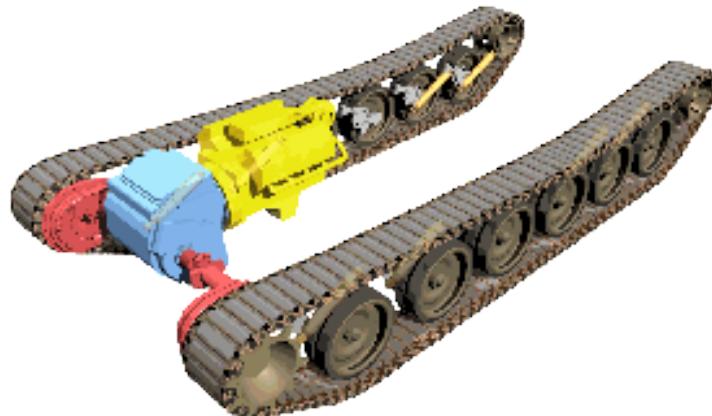




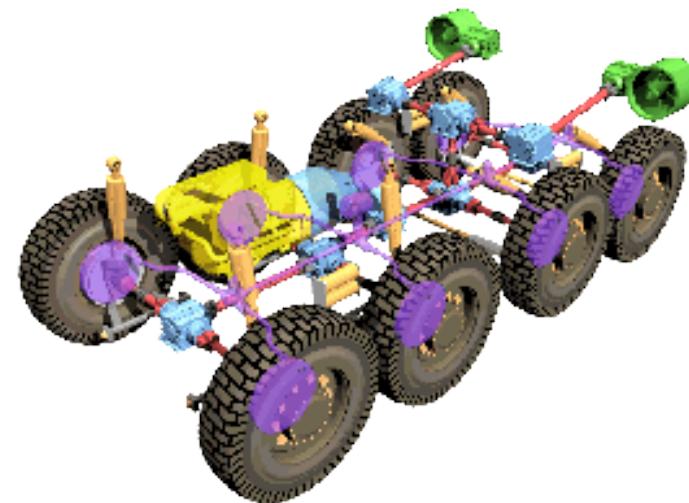
Configuration Considerations – Complexity



Tracks



Wheels



Wheeled Vehicles have a More Complicated Running Gear System, but Tracked Vehicles have a More Expensive Running Gear System



Vehicle Summary Pros / Cons



TRACKS

ADVANTAGES:

- Higher Cross Country Speeds
- Superior Obstacle and Gap Crossing
- Increased Slope Climbing Capability
- More Compact / Lower Silhouette

DISADVANTAGES:

- Higher Production, Maintenance, and Repair Costs
- Fewer Commercial Components
- Not Efficient in Sustained Highway Travel
- More Vibration on Hard Surface

WHEELS

ADVANTAGES:

- Capable of Maintaining Higher Speeds on Roads
- More Fuel Efficient (over Hard Surfaces)
- Less Cost Per Mile of Operation (over Hard Surfaces)
- Ability to Use Commercial Components
- Reduced Production Costs (Below 20 tons)
- Lower Maintenance and Repair Costs

DISADVANTAGES:

- Less Obstacle and Gap Crossing Capability
- Requires Stockage of More Spare Parts
- Less Stable Gun Platform (Tire Flex)
- Poor Soft Soil Performance over 25 tons



We Want Both





Vehicle Width can be a Problem



NATO Troops
Afghanistan



Vehicle Length can be a Problem



NATO Troops
Afghanistan



Sometimes the Road is too Narrow



NATO Troops
Afghanistan



Sometimes the Road Fails





Sometimes the Road is Rough



NATO Troops
Afghanistan



Sometimes the Vehicles Fail





A lot



NATO Troops
Afghanistan



The Road may be Unstable



NATO Troops
Afghanistan



The Road may Collapse



NATO Troops
Afghanistan



The Bridge may be Unsafe



NATO Troops
Afghanistan



May not Trust the Bridge



NATO Troops
Afghanistan



May want to Swim



NATO Troops
Afghanistan



Traverse All Terrains





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RDECOM
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

In All Climates





Mud can be an Issue for Wheels



NATO Troops
Afghanistan



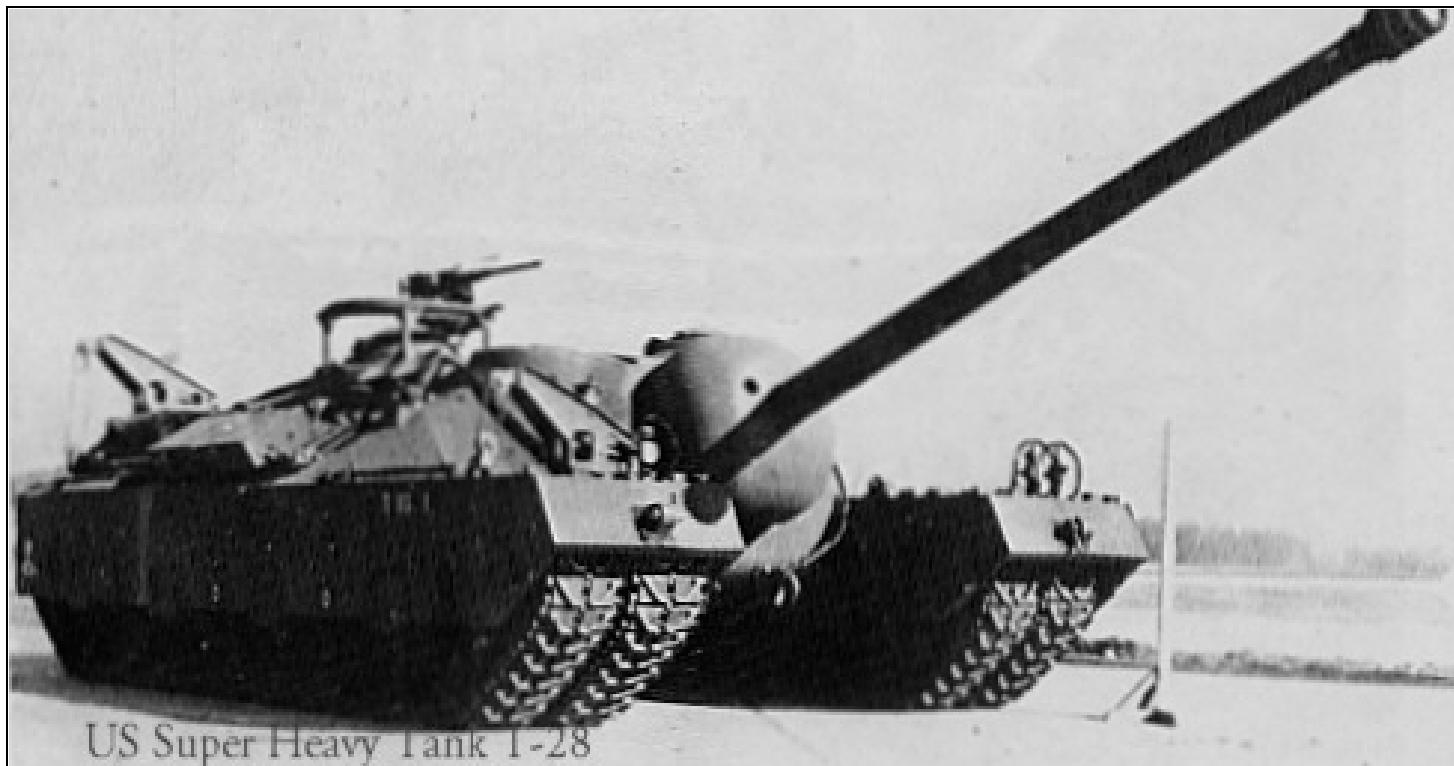
Mud Can be an Issue for Tracks





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Too Much of a Good Thing





Sometimes the Driver is Wild





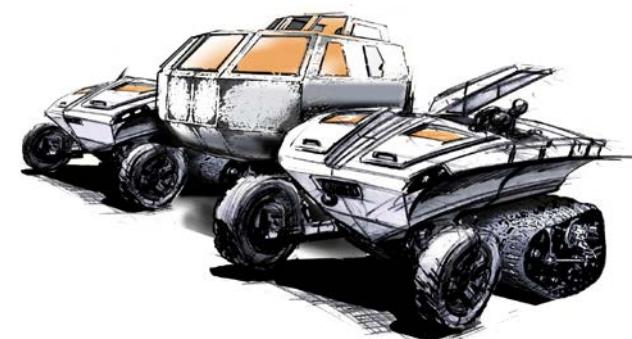
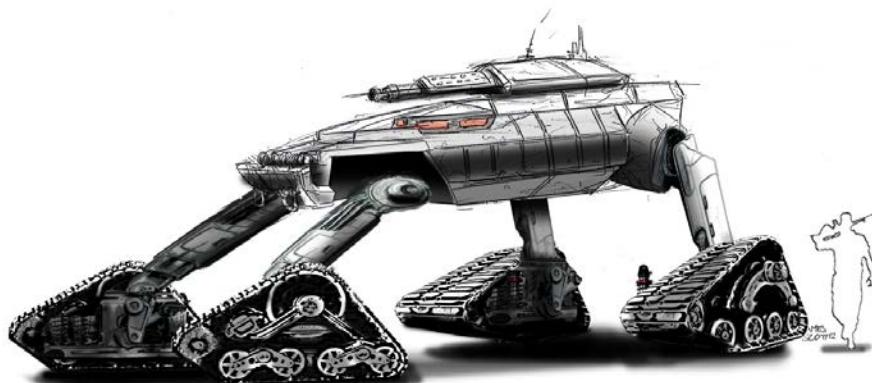
Sometimes Old Way still Works



NATO Troops
Afghanistan



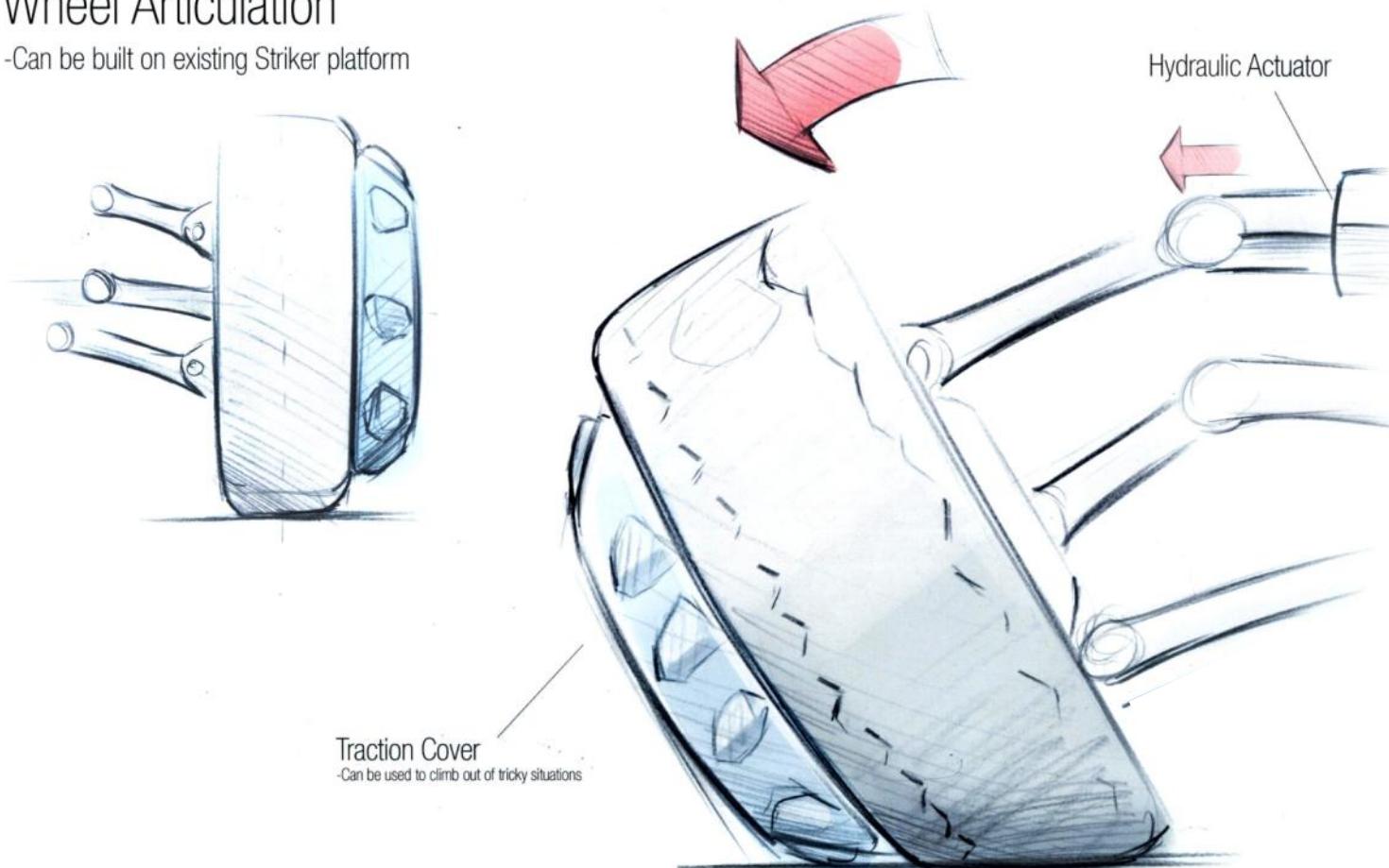
Good Luck and
Be Creative





Wheel Articulation

-Can be built on existing Striker platform





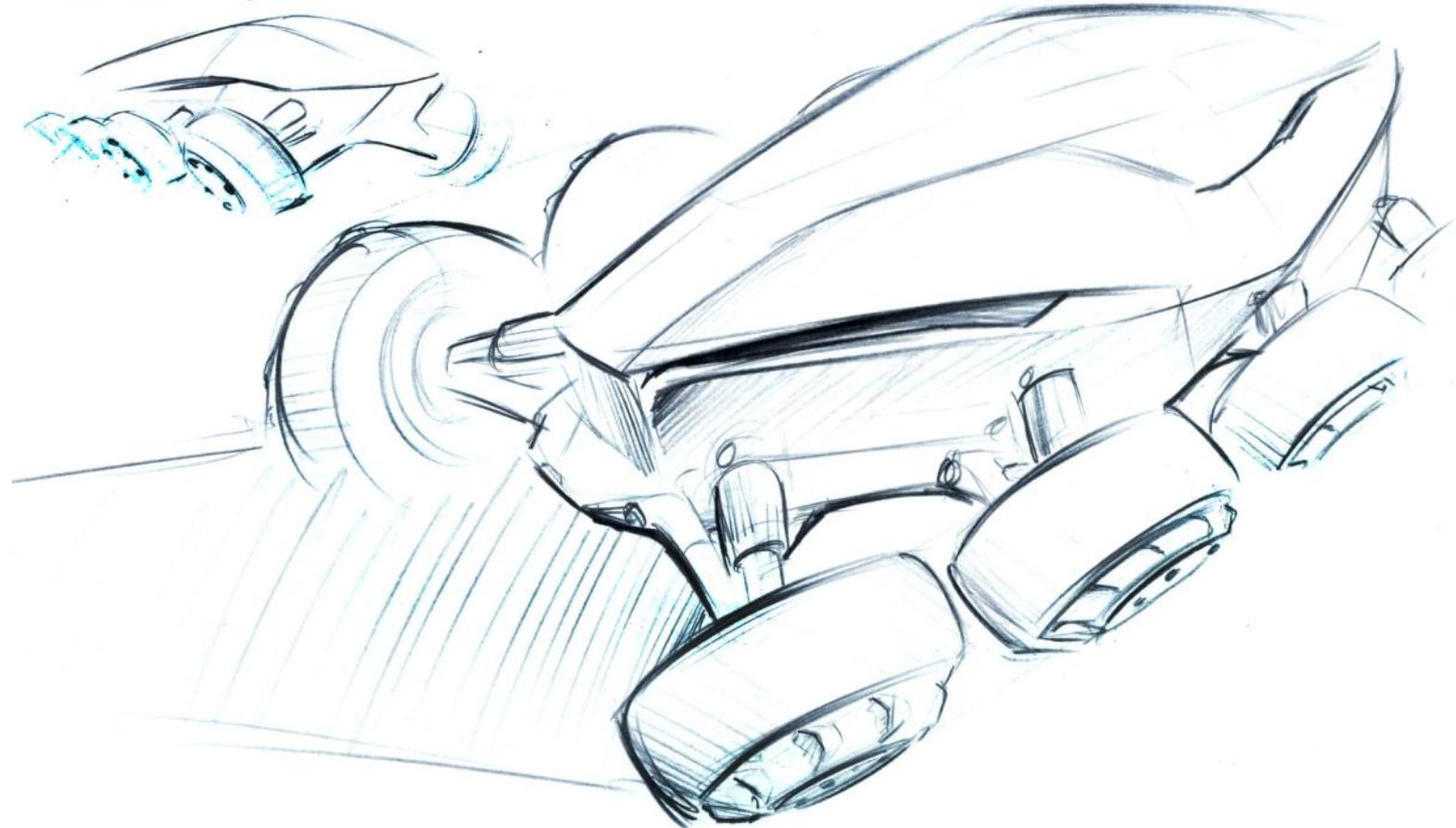
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CCS - Mobility Demonstrator Ideations



Final View

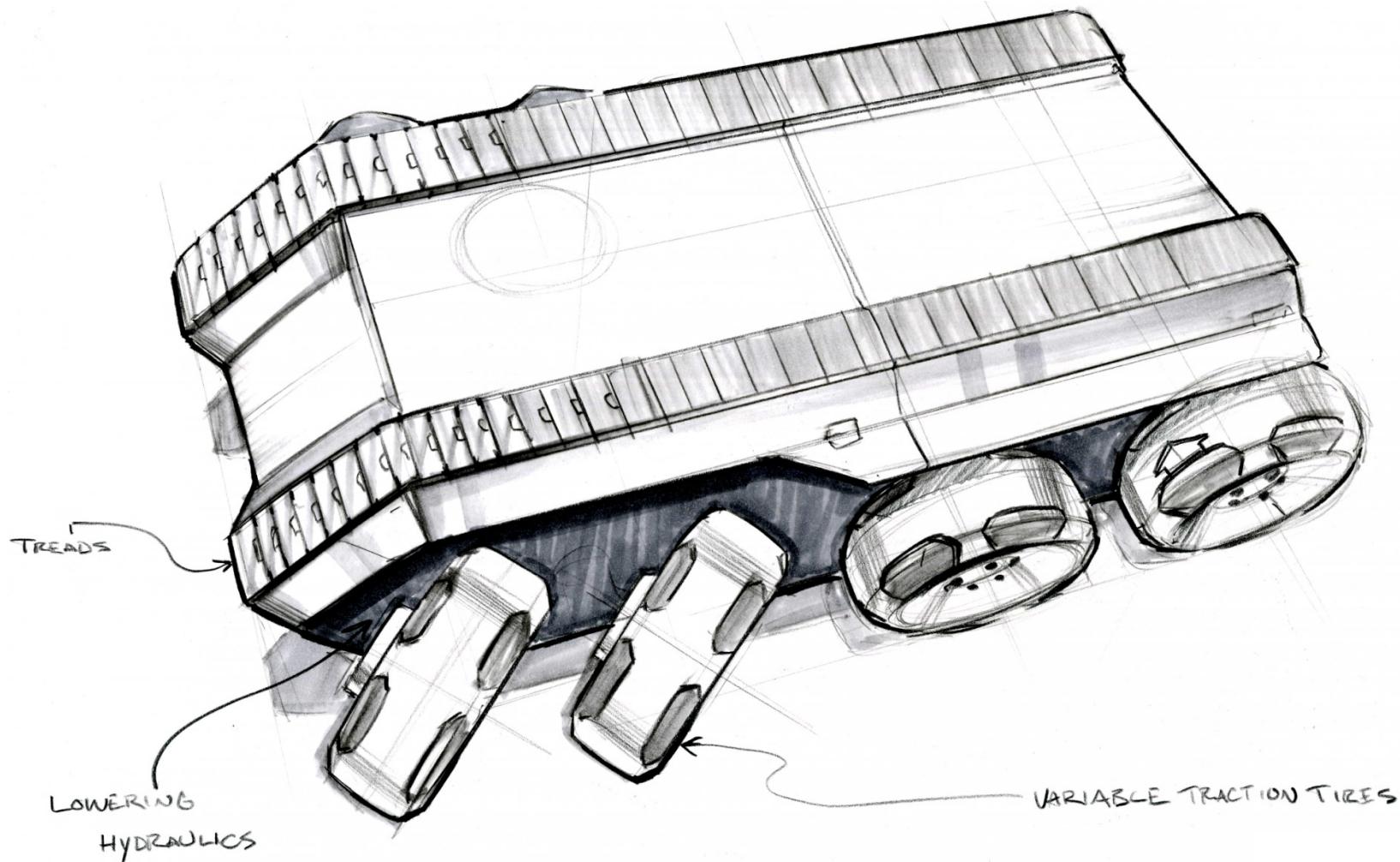
-Positive Camber Design





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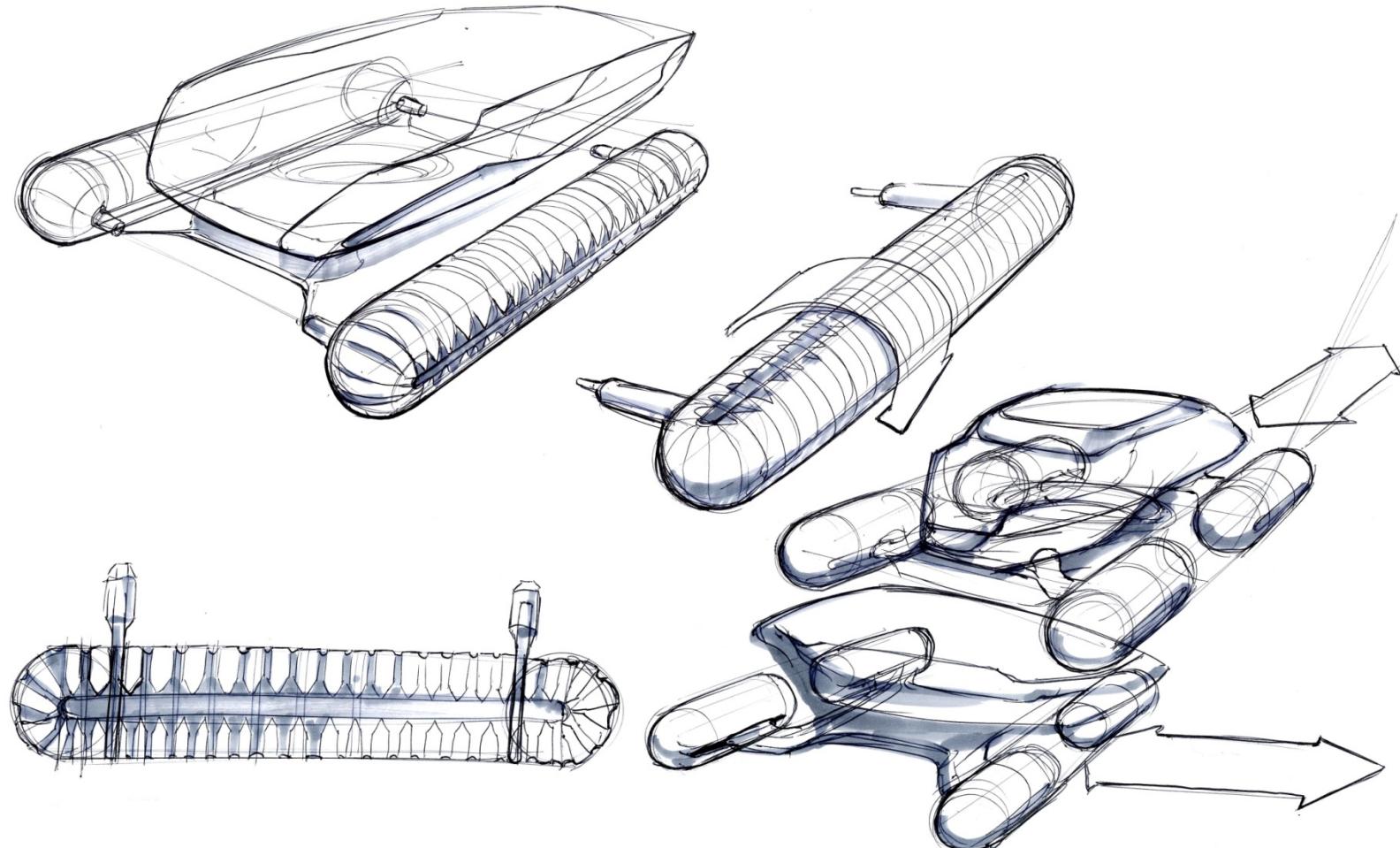


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CCS - Mobility Demonstrator Ideations



HYBRID TRACK/WHEELS



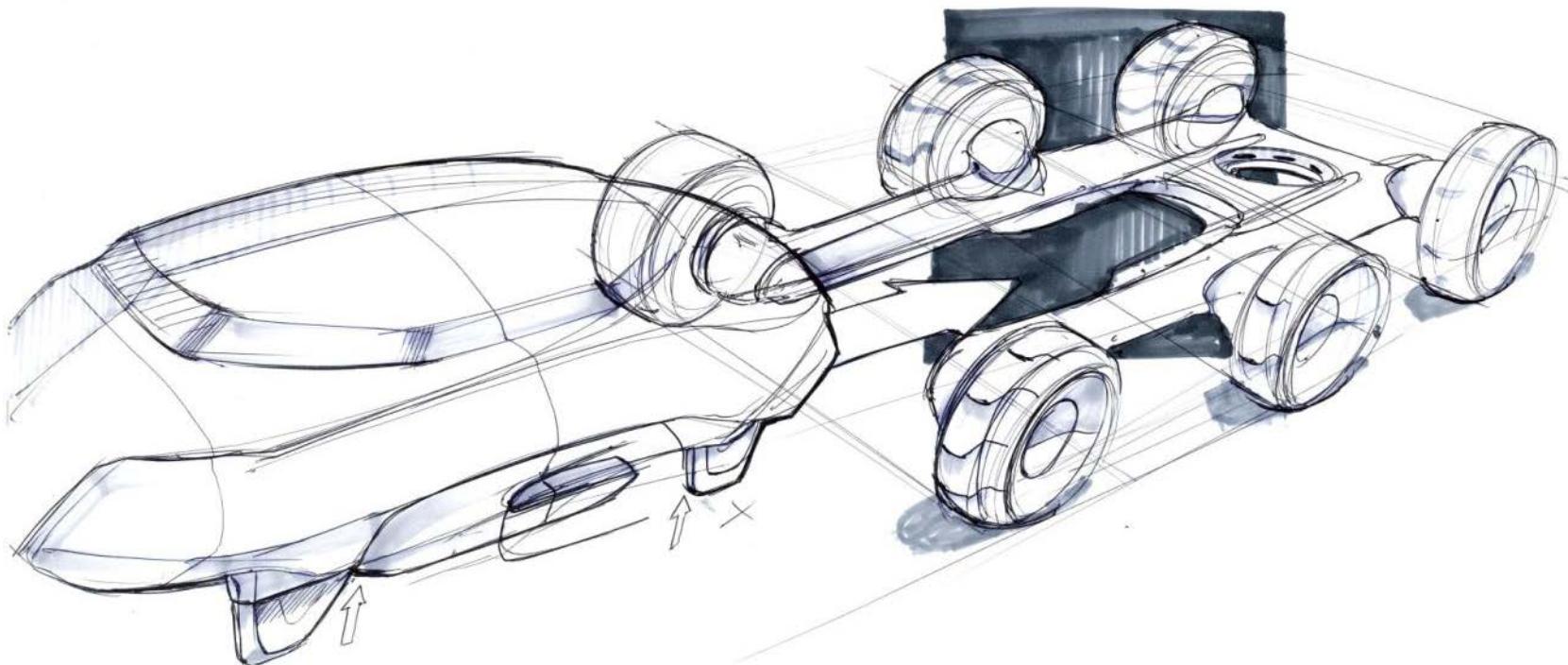
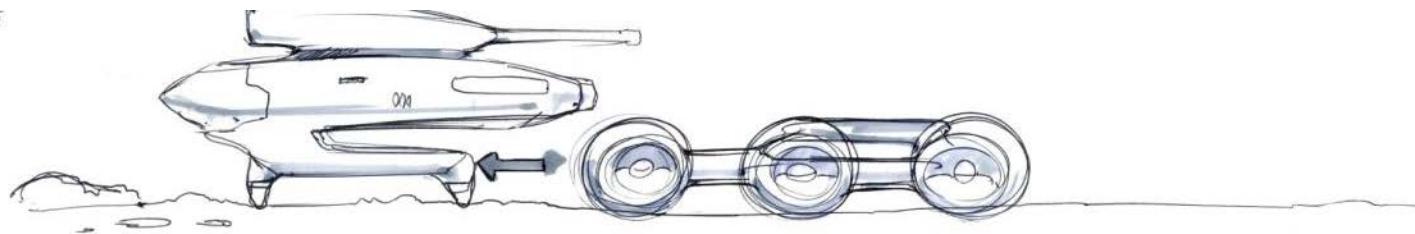


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CCS - Mobility Demonstrator Ideations



WHEELS





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CCS - Mobility Demonstrator Ideations



CVT TREAD

CONTINUOUSLY
VARIABLE
TRANSMISSION

CROSS - COUNTRY

FIXED IN REAR
FOR OCCUPANT SPACE

STEERABLE IN FRONT
(PRIMARY FOR ROAD)

BEVELED SURFACES INSIDE
EACH WHEEL PLATE

ENGAGEMENT SURFACE INSIDE
LIP OF WHEEL

UP

TRANSITION

DOWN

ON-ROAD



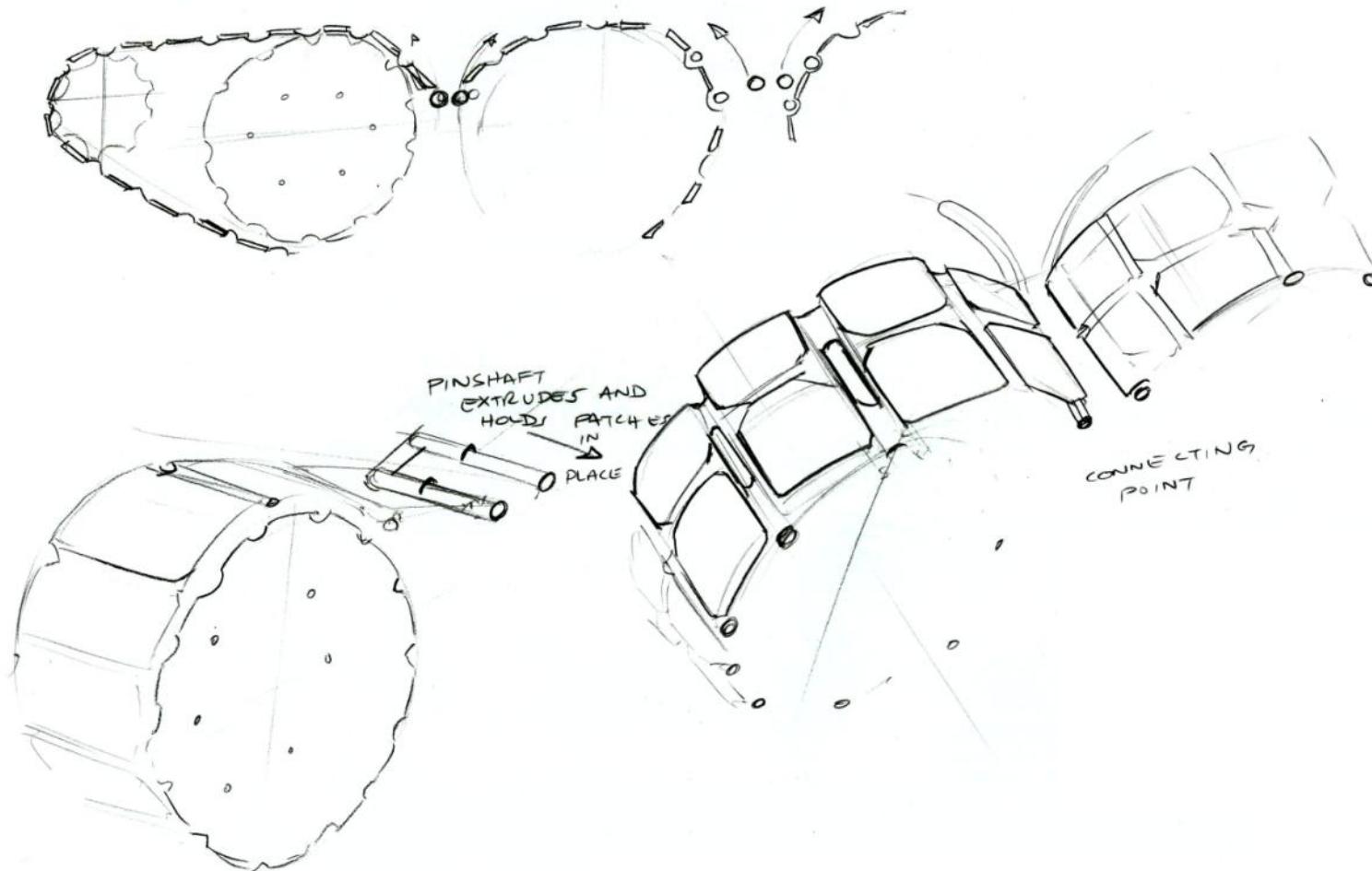
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CCS - Mobility Demonstrator Ideations



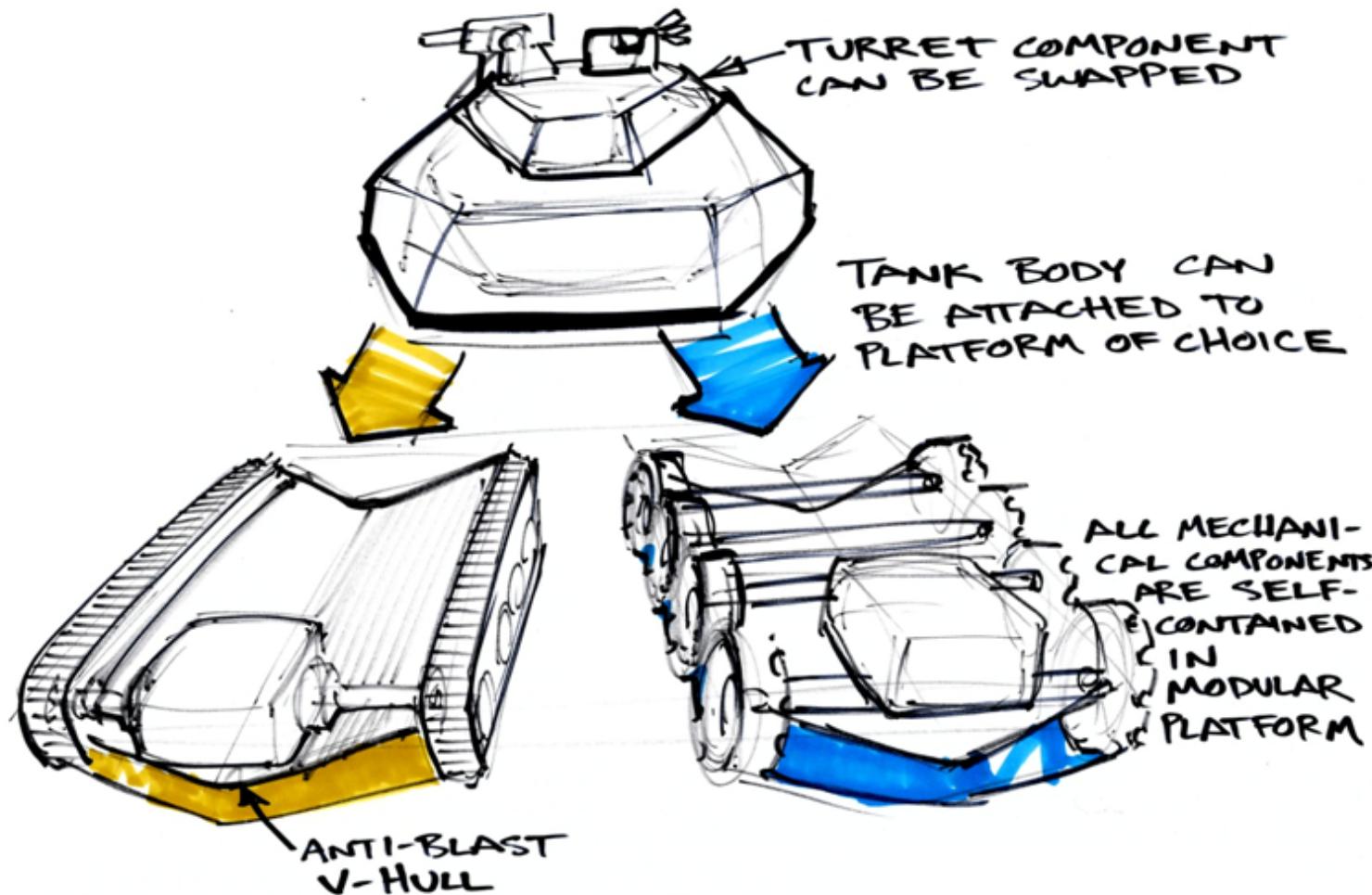
INTEGRATED WHEEL TRACKS

ASSEMBLY IS THE MAIN ISSUE





CCS - Mobility Demonstrator Ideations



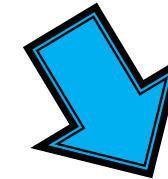
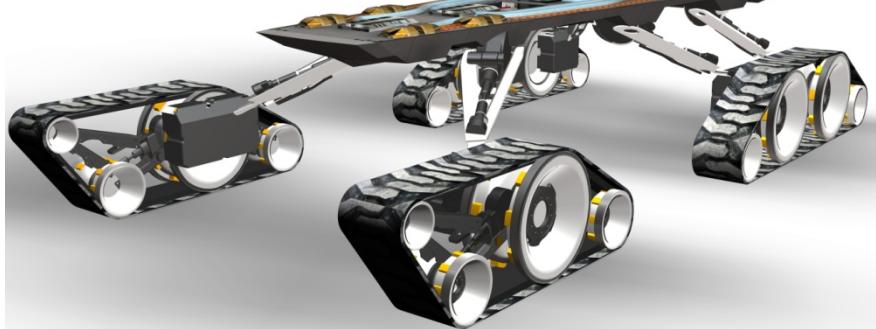


Body-On-Carrier Concept Vehicle or Modular Chassis Concept



Tracked or Wheeled Carrier
can be used depending on
mission

Tracked or Wheeled
solution can be
integrated at the
Depot or Assembly
Line level





Body-On-Carrier Concept Vehicle or Modular Chassis Concept





Body-On-Carrier Concept Vehicle Wheeled Solution





Body-On-Carrier Concept Vehicle Wheeled Solution





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Body-On-Carrier Concept Vehicle Tracked Solution





Path Forward Concepts

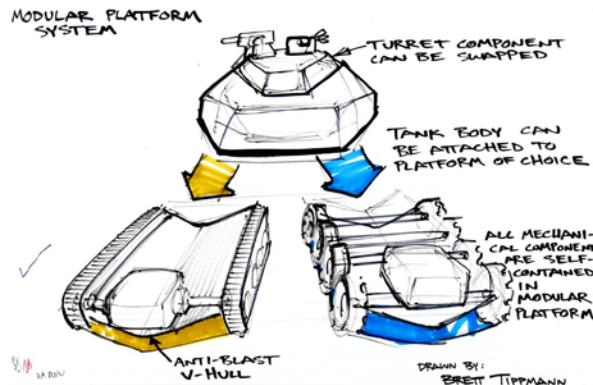
Exercise IV



COA I – Modular Chassis

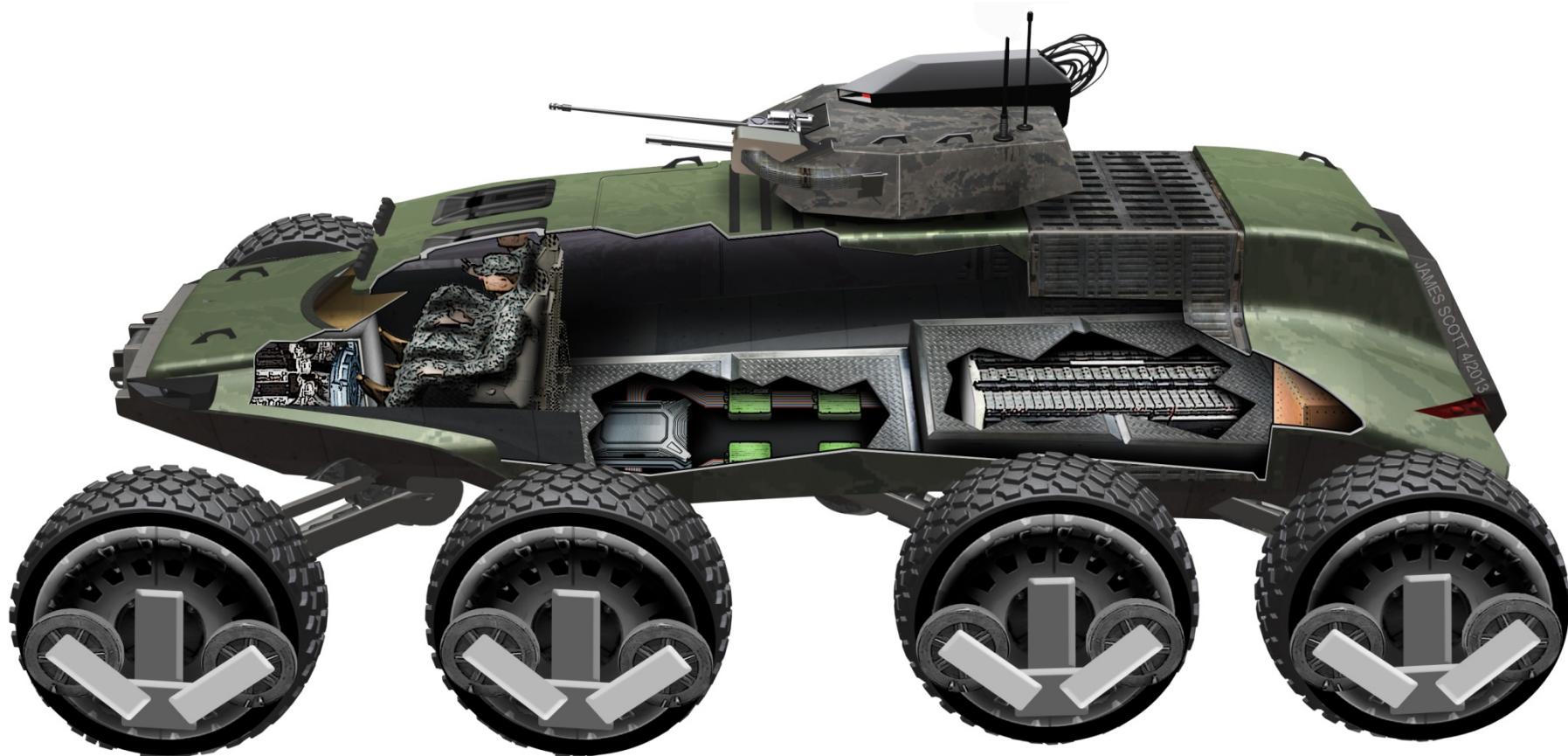
COA II – Modular Running Gear System

COA III – “Morphing” Track to Wheels System





Initial Mobility Demonstrator Concept



COA III – “Morphing” Track to Wheels System



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Sequestration Wheel Concept Vehicle





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Sequestration Tracked Concept Vehicle



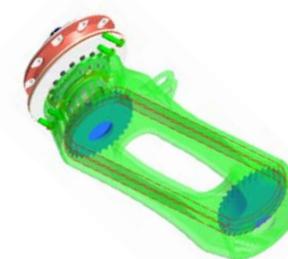
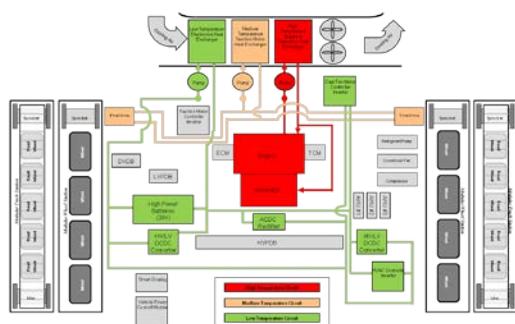


Subsystem-by-Subsystem Evaluation

Exercise V



- Wheels to Track Transformation Sub Systems
- Advanced Suspension Sub Systems
- Advanced Power Pack Sub Systems
- Advanced Thermal Management Systems
- Electrified Propulsion Systems
- Advanced Energy Storage Systems





Tire To Track Transformation Sub Systems





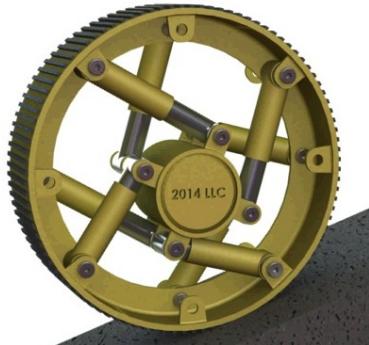
Future Airless Wheel Technologies



Company: Structural Dynamics Cons. Eng. Co

Technology: Shweel Tire /Shock-Wheel

Description: Rigid wheel with attached tread connected with shock absorbers between wheel and hub.



Company: Michelin

Technology: TWEEL Airless Tire

Description: Airless tire/wheel with polymer spokes between tread and hub.



Company: Resilient Technologies (Polaris Defense)

Technology: Non-Pneumatic Tire

Description: Airless Tire/wheel with honeycombed shaped polymer supporting structure between tread and hub.



Company: Scitech Industries

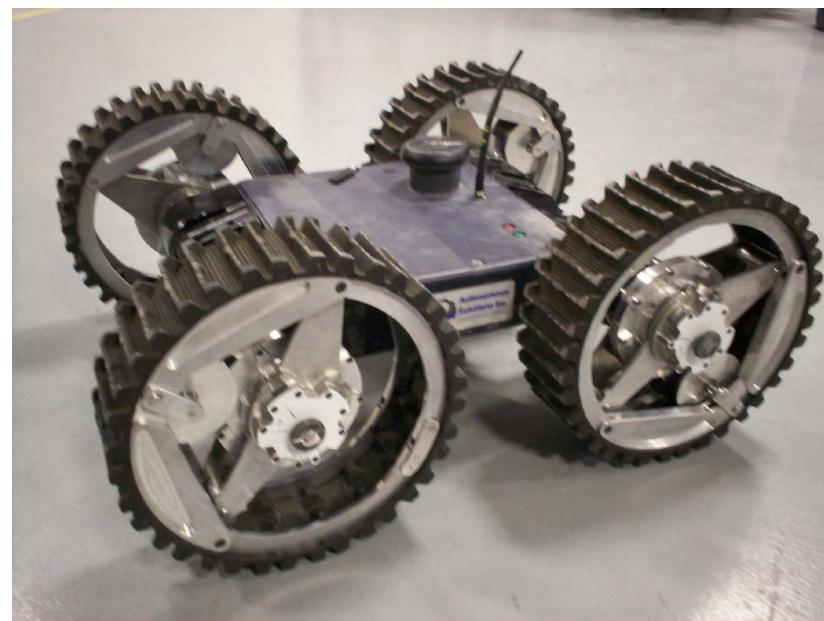
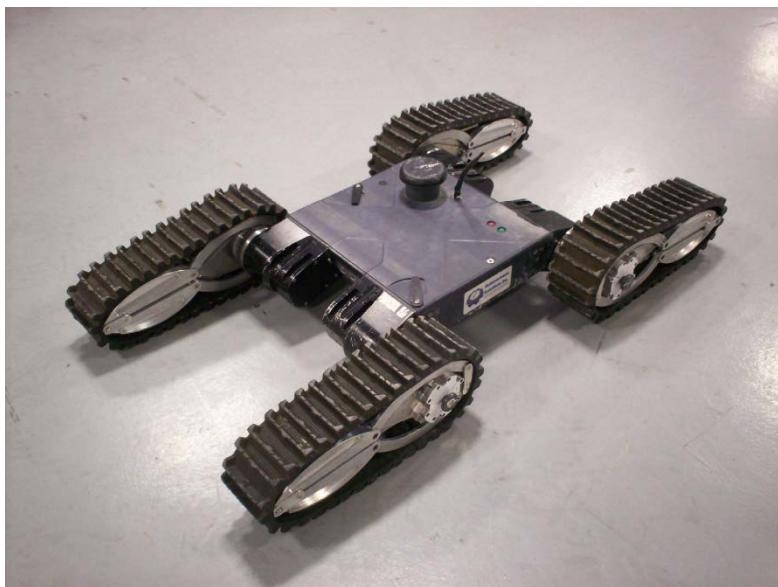
Technology: Airless Tire

Description: Airless tire which uses U-shaped springs made of epoxy or fiberglass to mechanically support the load





Roadrunner Tire to Tracks System



Roadrunner by Autonomous Solutions



Track -N - Go System





MATTRACKs Tire to Track Transformation System



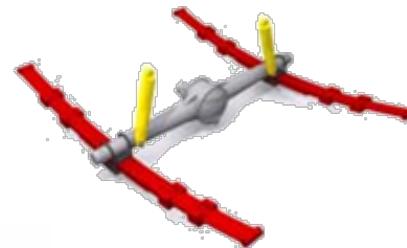
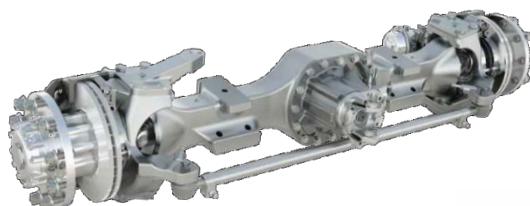


Advanced Suspension Sub Systems



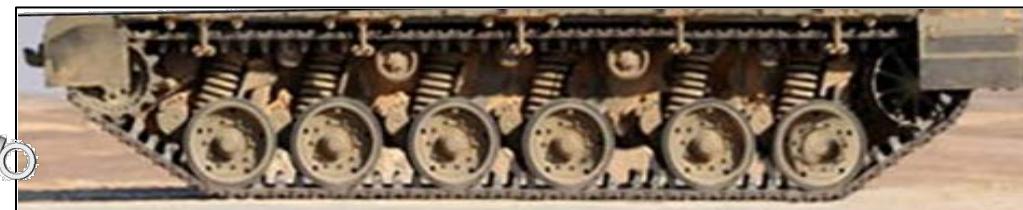
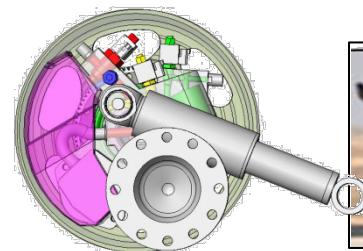


- Wheeled vehicle suspension systems continue to evolve over past 50 years:
 - Independent suspensions
 - Dependant suspension (solid axles)
 - Trailing arms
- The biggest advancement in these systems has been in controls development.
- Suspension control systems have been used to improve ride and handling.
- Controls are now being developed to improve occupant safety through ride height adjust.



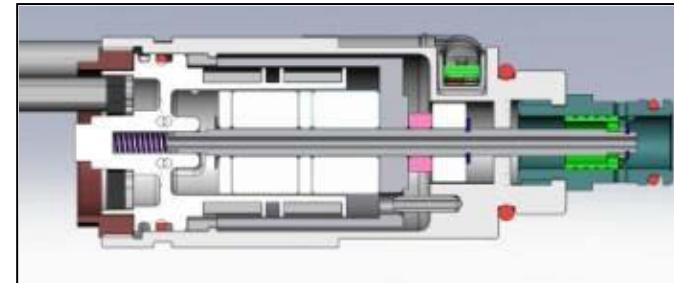


- Tracked vehicle suspensions continue to evolve over the past 70 years.
 - Trailing arm suspensions with torsion bar springs.
 - Either linear or rotary dampers
 - Simple linear track tensioners or self-adjusting track tensioners
- The biggest advancement in these systems has been pneumatic external road-arm design (external suspensions).
- There has been some research into semi-active suspension control systems to improve ride, but nothing fielded.





- Types / levels of vehicle suspension systems
 - Passive
 - Semi-Active (Dampers are controlled)
 - Fully-Active (Springs and/or dampers are controlled)



Variable Orifice
- *Semi-active option* -

Passive Suspension

- Fixed Spring and Damper Rates
- Trade-off between Ride Quality and Handling



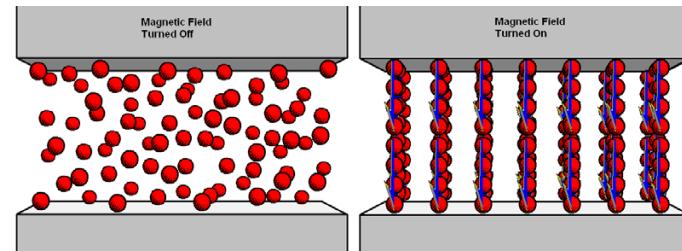
Semi-Active Suspension

- Low power solution
- Variable damping
- Improved ride quality and handling



Fully Active Suspension

- Variable ride height
- Energy recovery
- Maximum improvement in ride quality and handling



Magneto-Rheological Fluid
- *Semi-active option* -



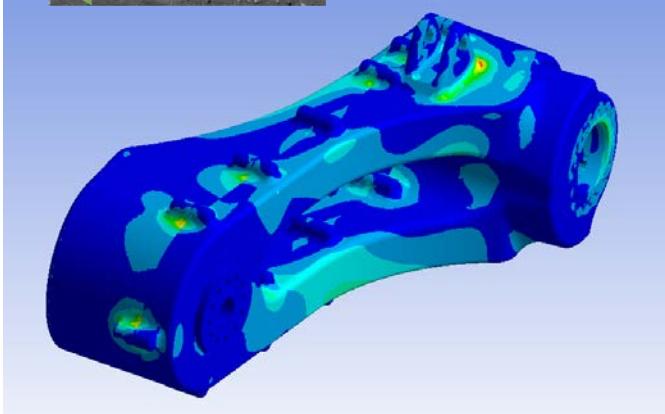
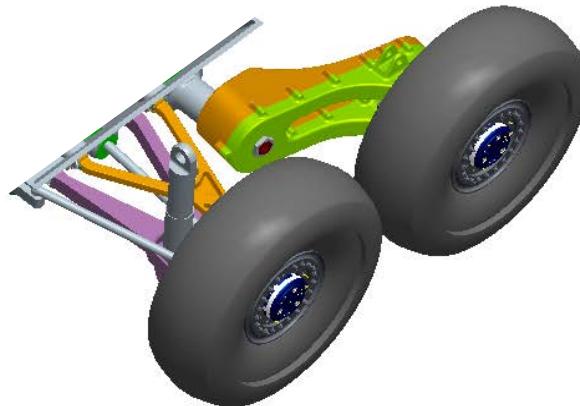
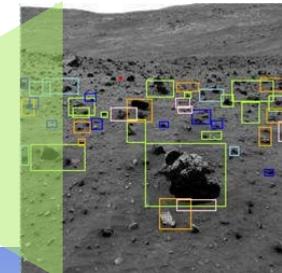
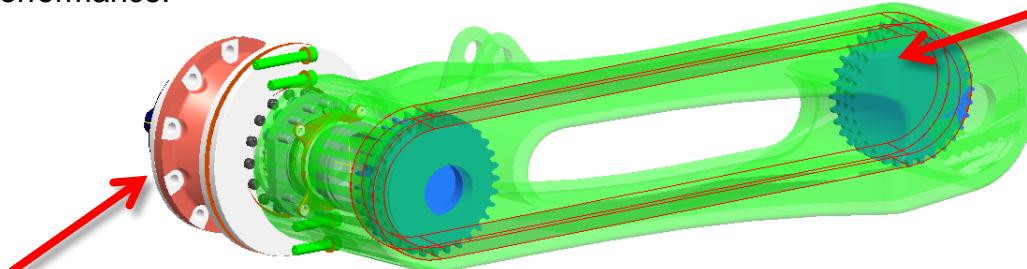
Advanced Suspension Systems



Suspension technology will evolve to become fully predictive of the terrain environment it's operating on. Controls algorithms will lead the realm of possible for vehicle performance.

In Body Motor

Drive Spindle



FAULT REP

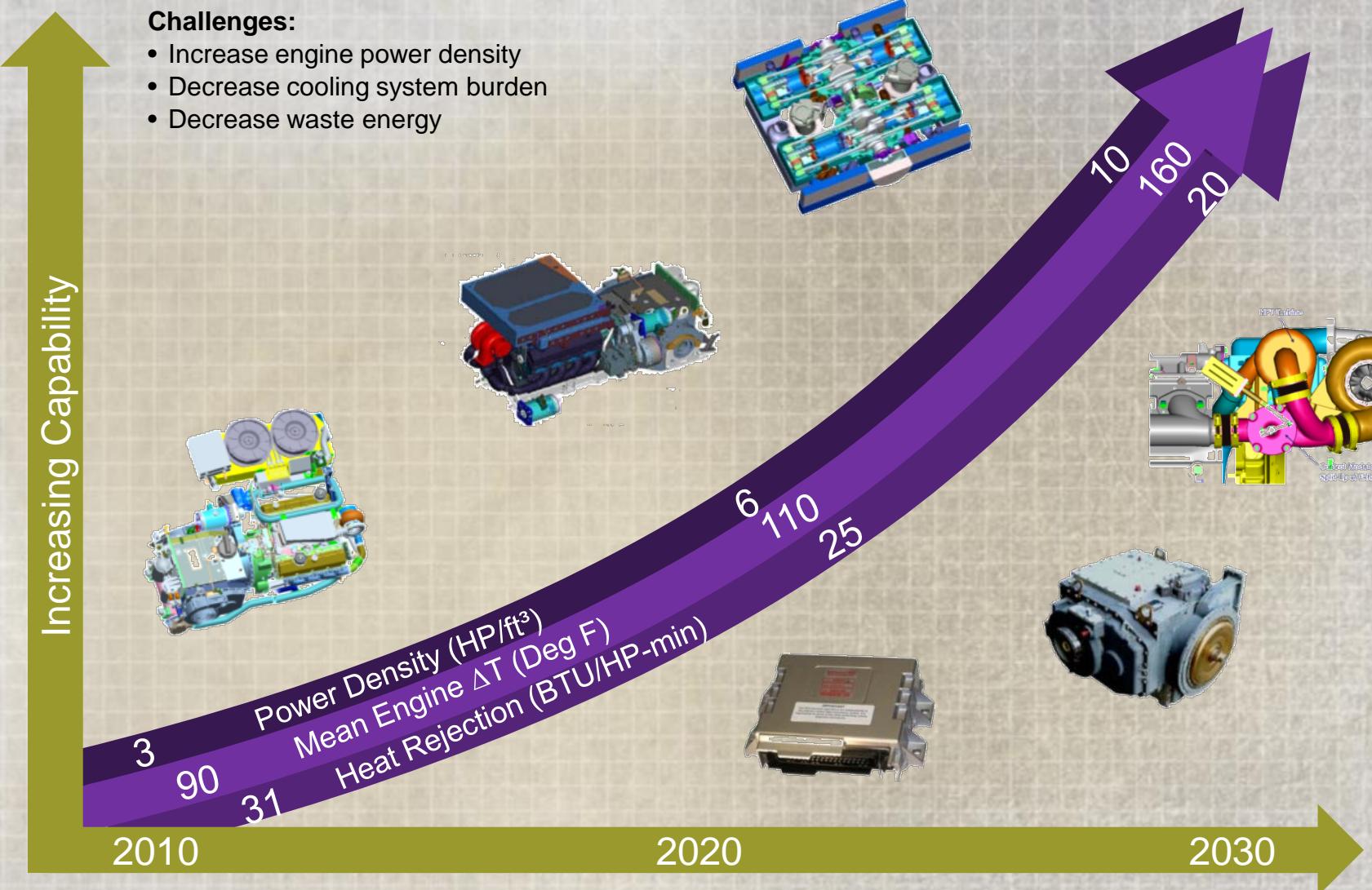


Advanced Power Pack Sub Systems



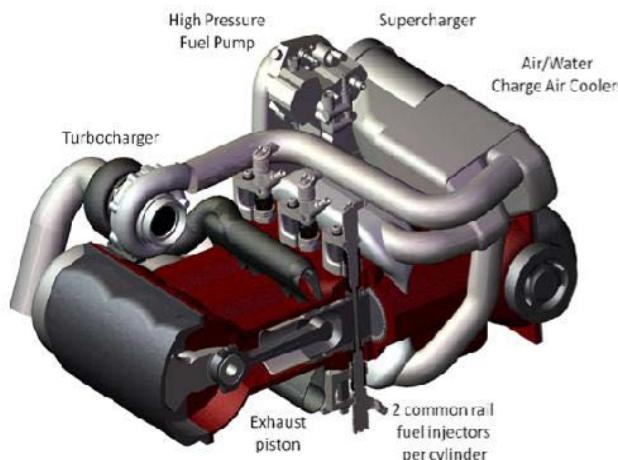


Power Plant Challenges





High Power Dense Engines



Next Generation Engine



HOTHED Engine



Advanced Fuel Cells



Free-piston Linear Generator



Next Generation Combat Engine

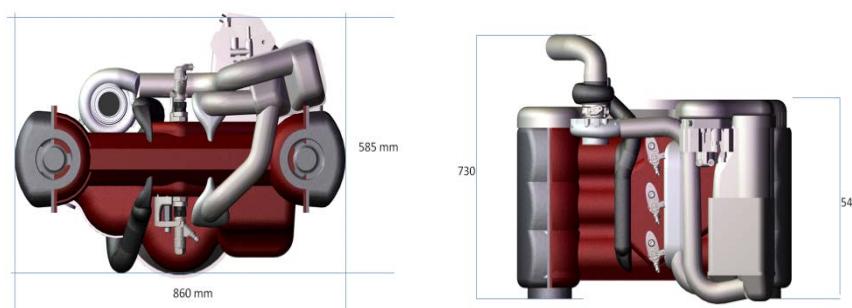
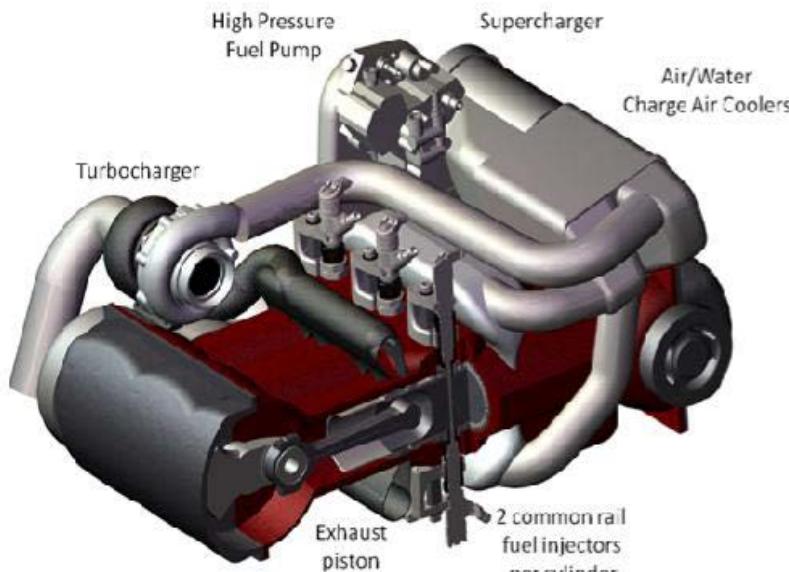


Figure 2a. Front View of 3-Cylinder Engine Concept

Figure 2b. Plan View of 3-Cylinder Engine Concept

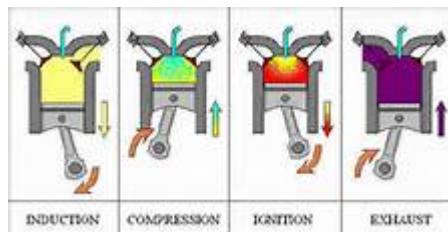
Opposed piston high output 2-stroke engine

Payoffs:

- Higher installed propulsion system power density-twice the power in same volume.
- Less volume under armor (weight save)
- Lower cooling system thermal burden with less cooling fan hp draw.
- Improve fuel economy (15-20% improvement).
- Scalable engine family building blocks with high degree of commonality with reduce logistical burden (parts & maintenance).
- Restore mobility capabilities lost due to vehicle weight gains
- Compact design to improve under hood packaging flexibility
- Scalable Engine Family Specification (competitive).



High Operating Temperature, High Density Engine (HOTHED)



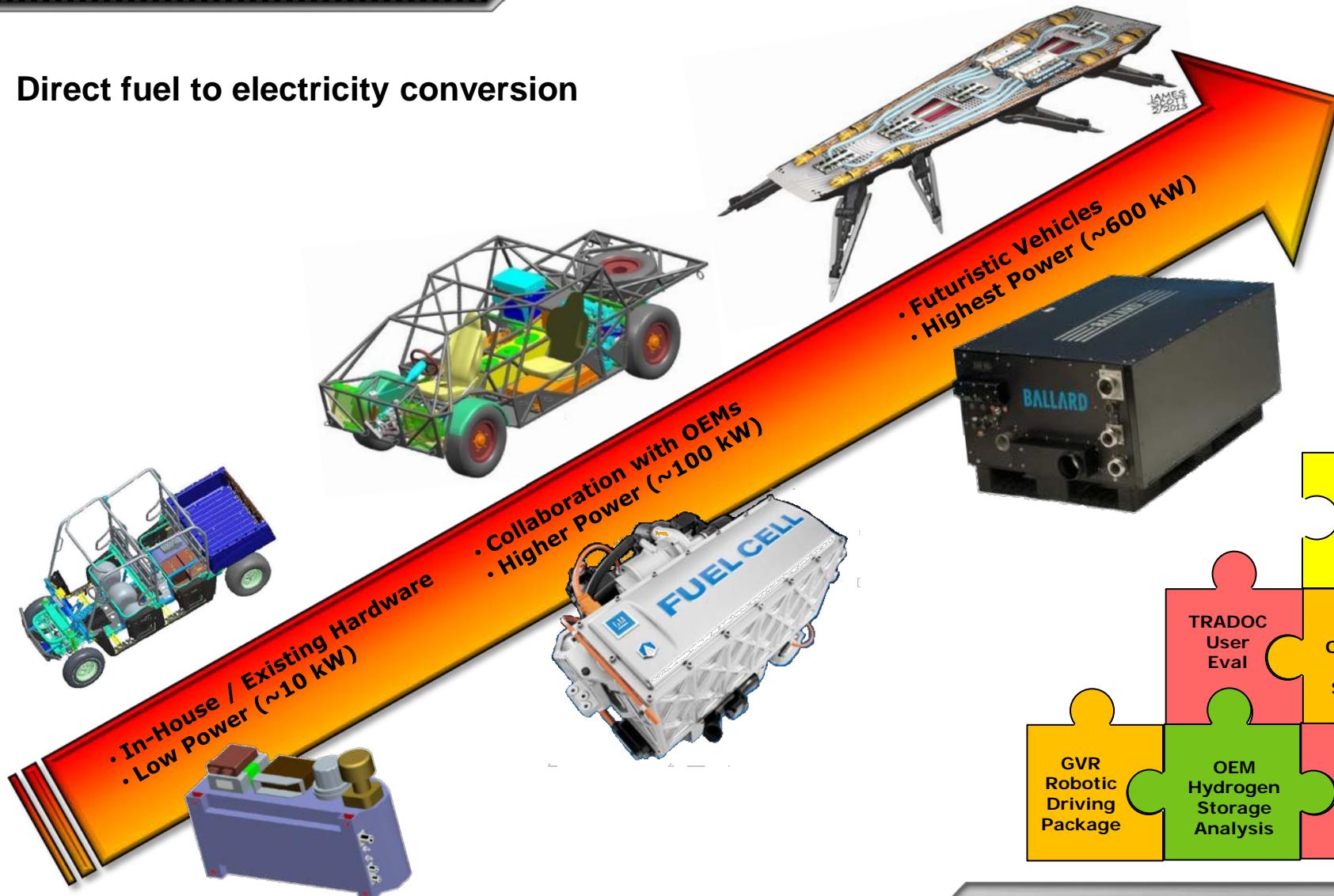
Higher operating temperature / decreased heat rejection engine.

Payoffs:

- Engine with increased installed power density for better packaging in future combat vehicles.
- Smaller thermal management system.
- Decreased engine friction for improved fuel efficiency.
- New air charging system for increased power density. Compact two-stage turbocharger systems.

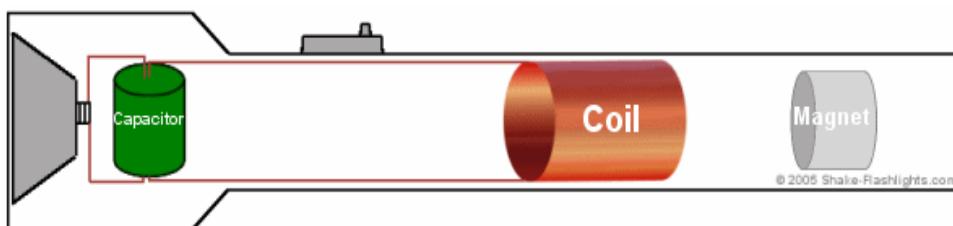


Direct fuel to electricity conversion





Free-Piston Linear Generator Concept



Faraday principle of electromagnetic energy to charge



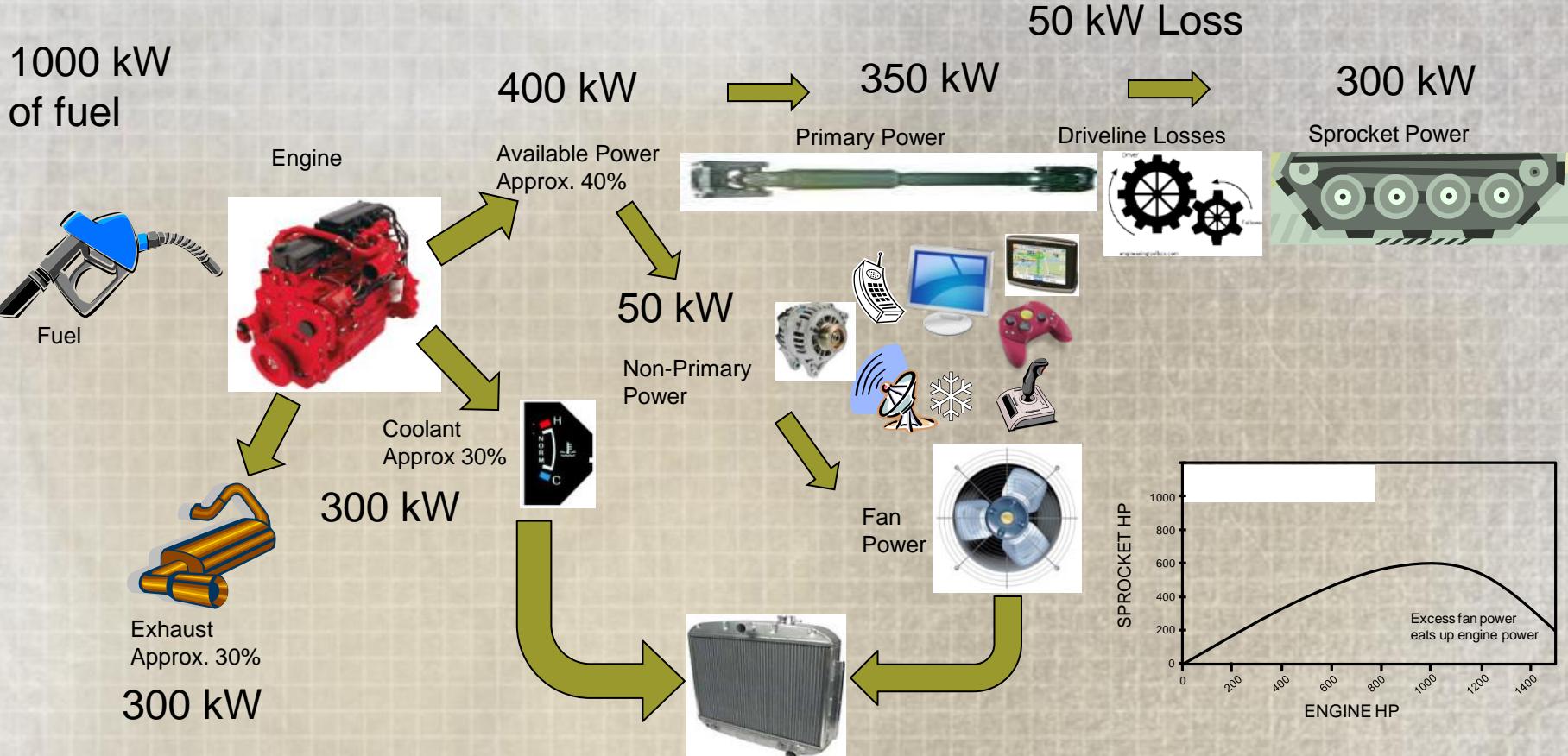


Advanced Thermal Management Sub Systems





Mechanical Drive Propulsion System Losses



Only 30% of fuel energy available at sprocket!!



Near Term Thermal (Improve Components)



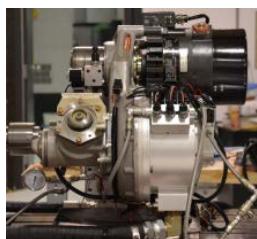
Improve Existing Component Technologies – efficient power take-off, thermoelectric generator muffler, fan geometry improvement, radiator materials.



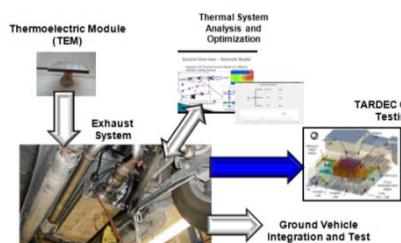
*Efficient
Fans*



*Efficient
Radiators*



Geared PTO



*Thermoelectric
Generator
Muffler*



*Electrified Fans
and Controller
Hardware*



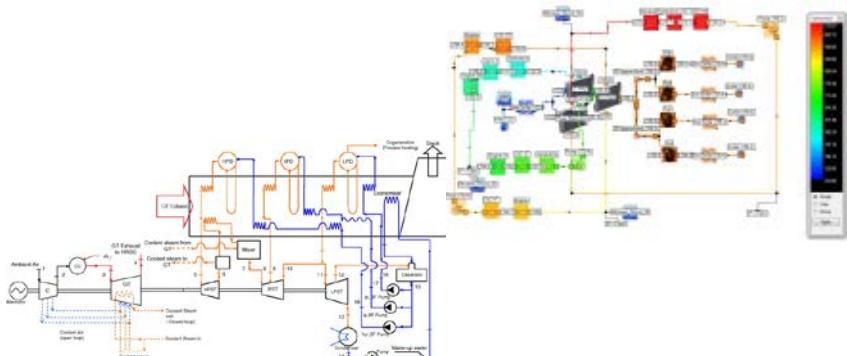
Mid Term Thermal (Systems Approach)



- System – begin integration of thermal loops and architecture optimization, common controller implementation, heat to electrical conversion with engine off
- Technologies – adaptable grills, advanced waste heat recovery, solid state cooling, turbocharging /turbocompounding



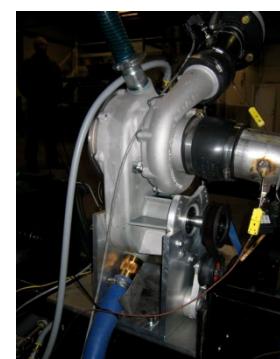
Advanced Waste Heat Recovery



Optimized Cooling Loops



Grills



Turbocharging



Control Module



Thermoelectric Power Generation

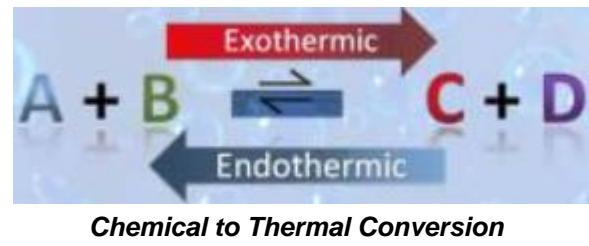
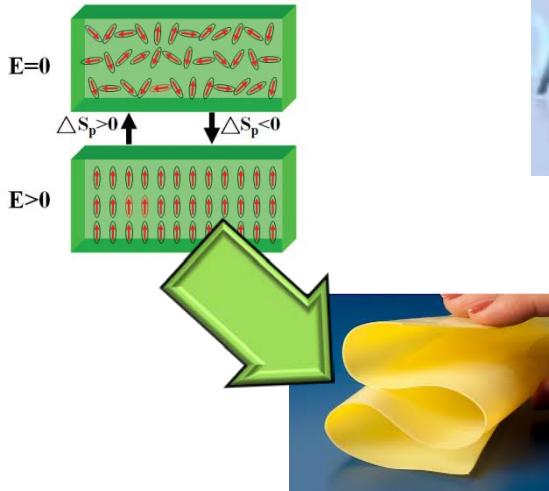


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Long Term Thermal (System-of-Systems Approach)



- System – develop components capable of handling multiple roles within thermal system
- Technologies – adaptive insulation, chemical to thermal conversion, thermal to electrical converting hoses, engine component thermal wraps, self-pumping hoses





Future Thermal Management



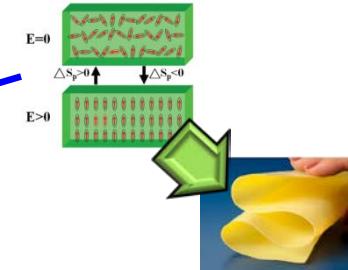
Thermoelectric Power Generation



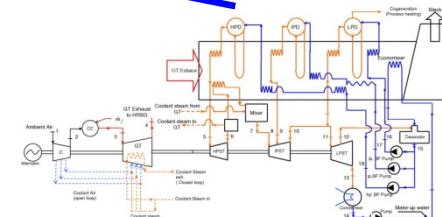
Intelligent Fans/Radiators



Advanced Hoses



Adaptive Insulation



Optimized Cooling Loops



Advanced Electrified Propulsion Sub Systems

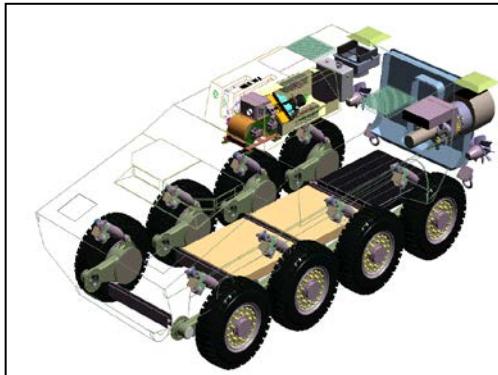




Electrified Propulsion – Why?

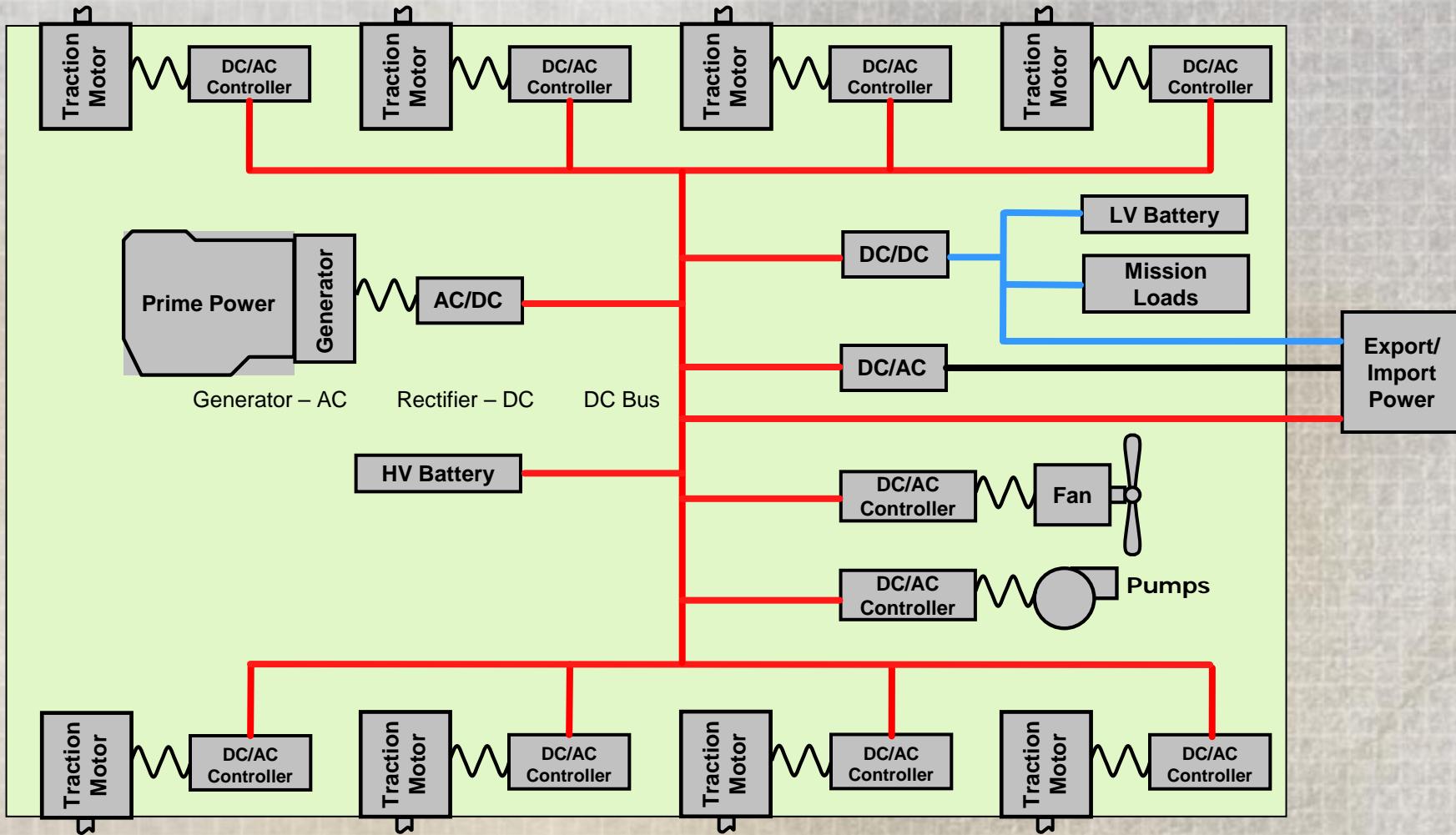


- Enables power for Future Weapons, Defense, and Communications
- Exportable Power Sharing
- Packaging Flexibility
- Enables unique powertrain architectures
- Burst Power for Mobility
- Silent Mobility (reduced thermal and audible signature)
- Silent Watch
- Potential Improvement in Fuel Economy.



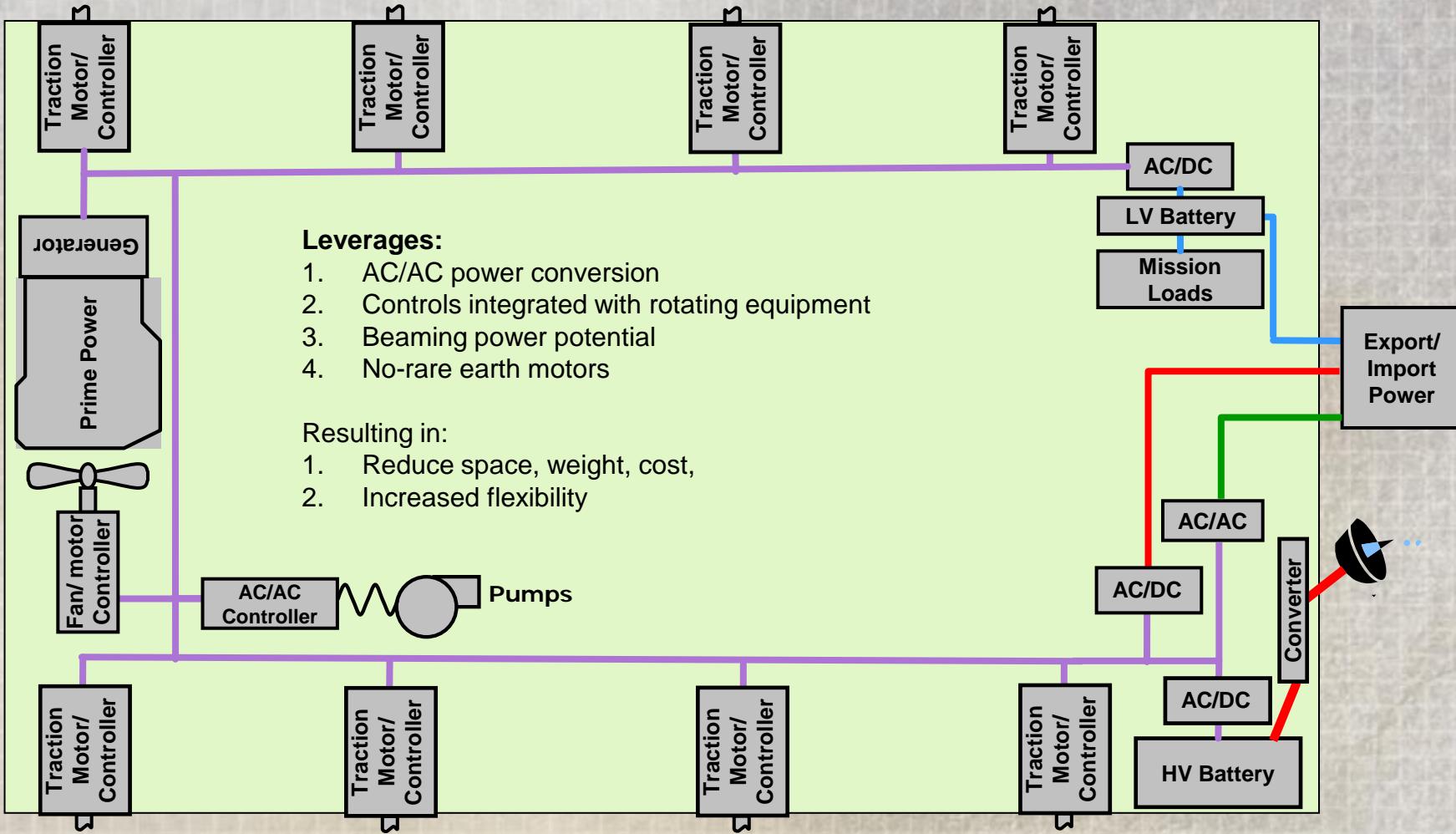


Electric Drive Architecture Today's approach





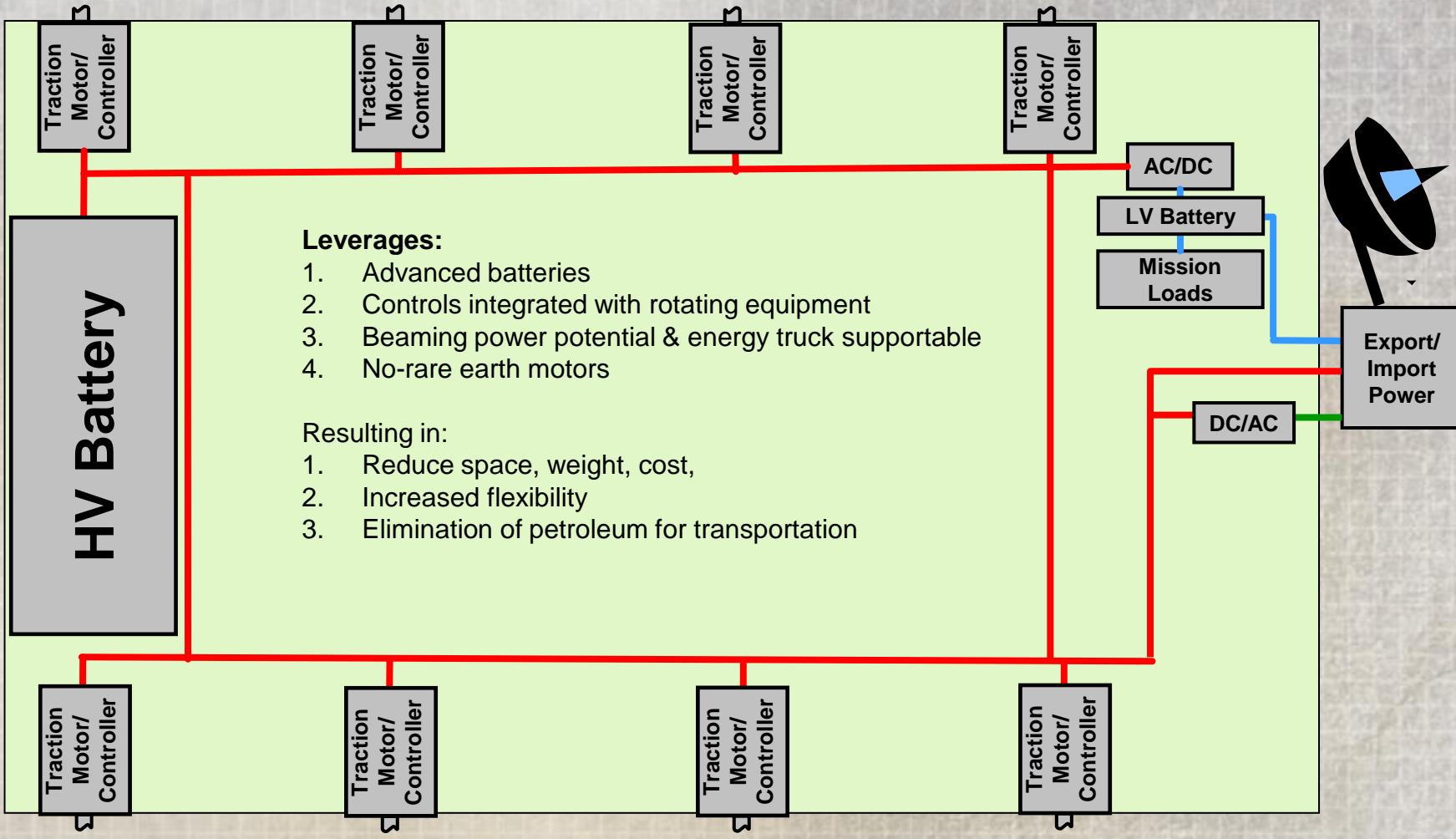
Electric Drive Architecture Tomorrows approach

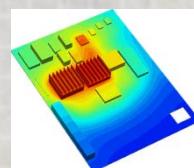




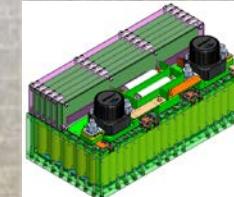
Electric Drive Architecture

Way, way out there approach

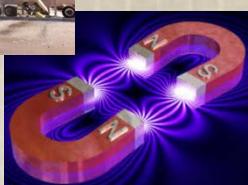




High Temperature electronics



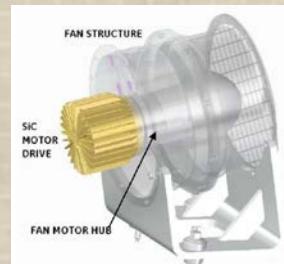
Advanced energy storage



Non-Rare Earth Magnets



High Density electronics



Integrated motor controllers



Beam Power to vehicles to reduce logistic trail

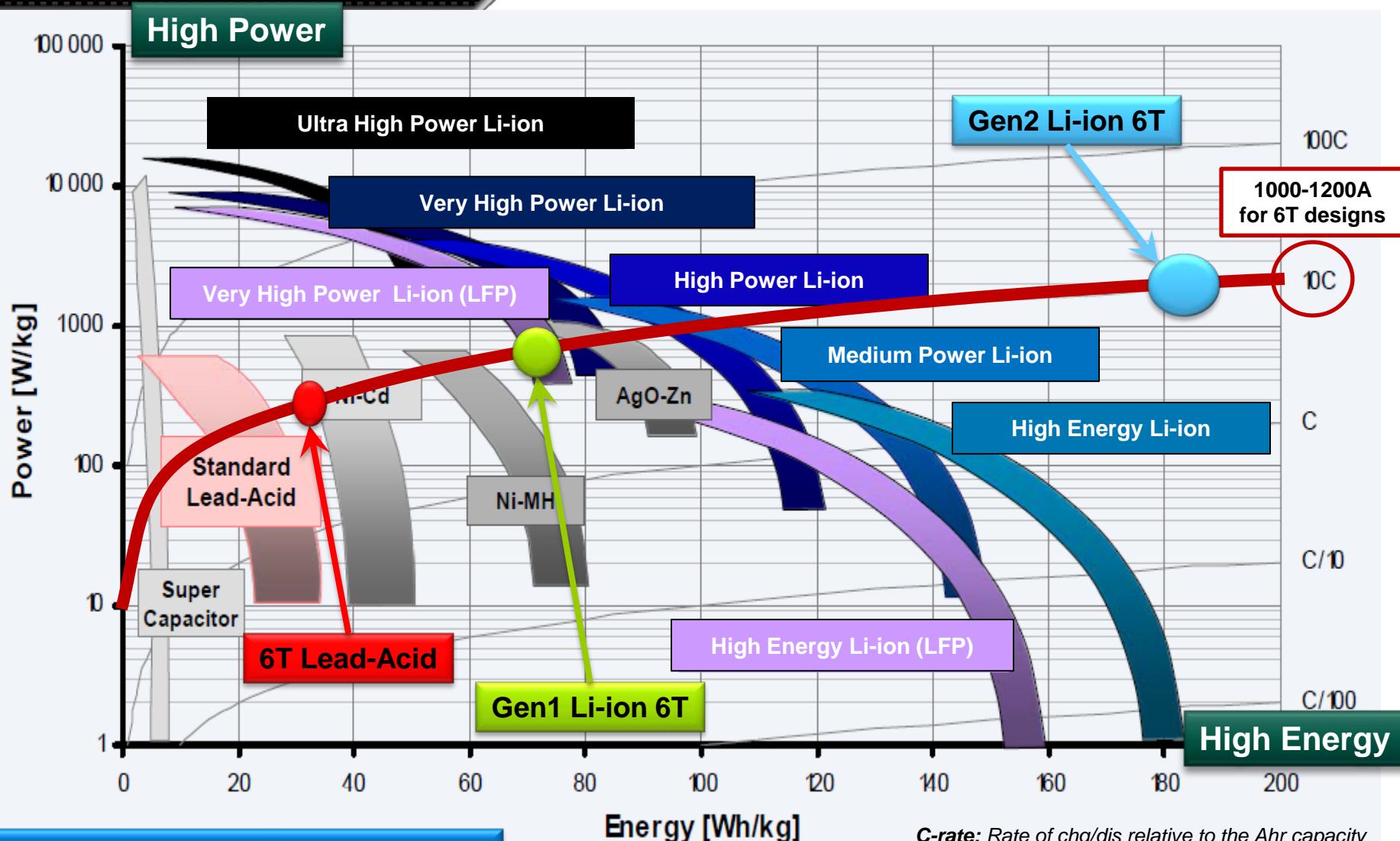


Advanced Energy Storage Sub Systems



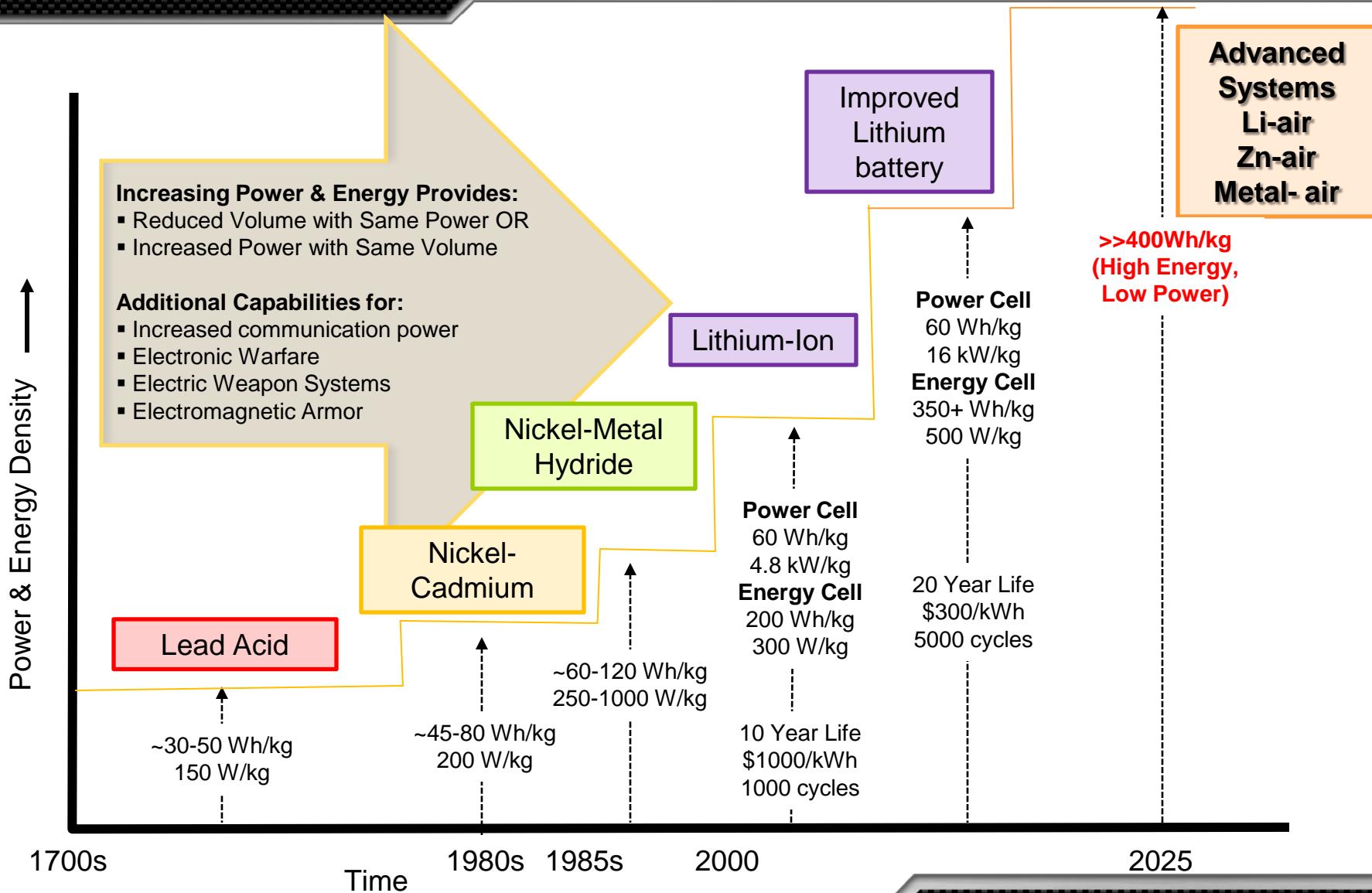


Power versus Energy



Where are we today...

C-rate: Rate of chg/dis relative to the Ahr capacity
(1C indicates battery discharged in 1 hour)

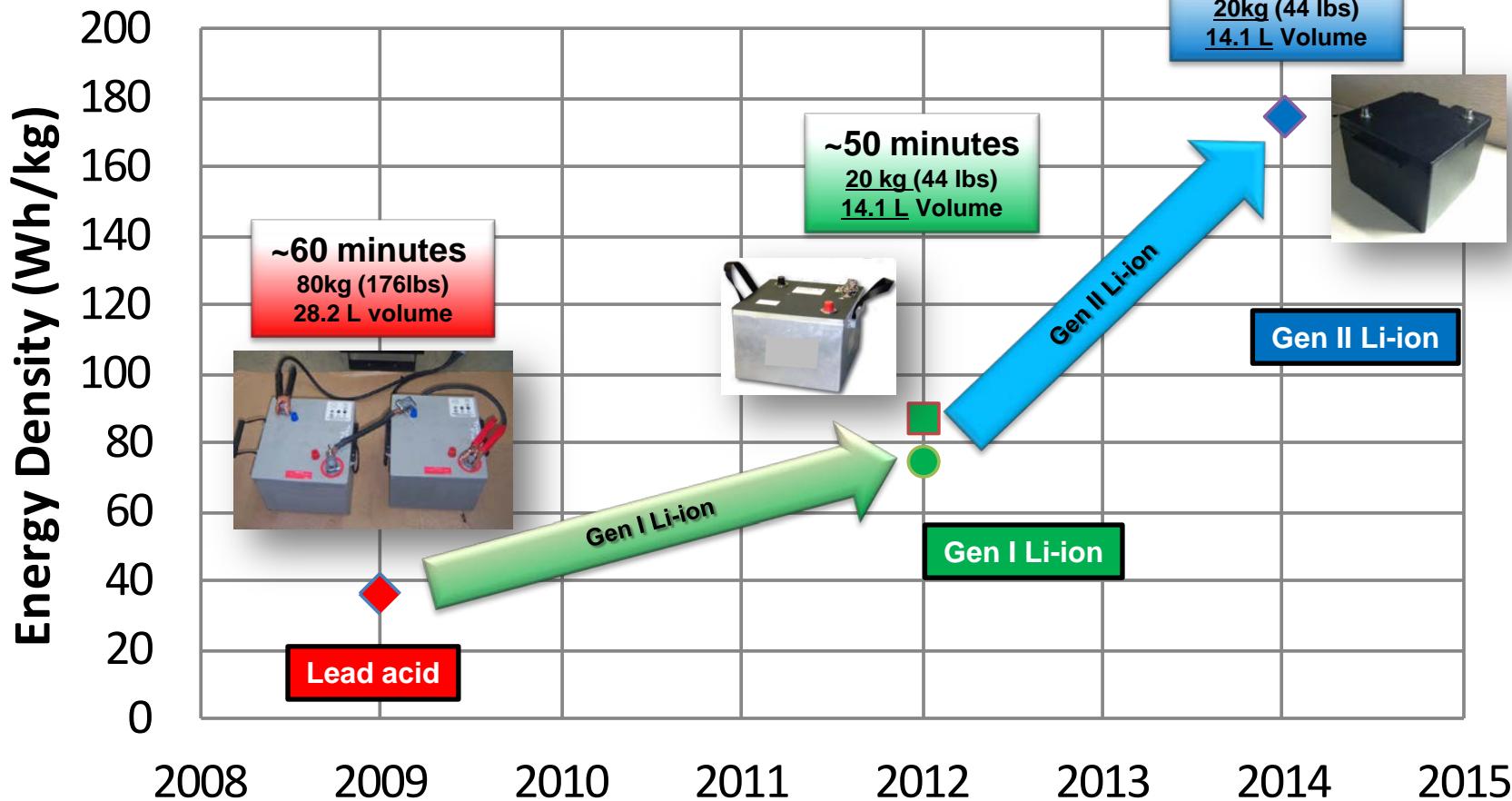




6T Li-ion Battery Development



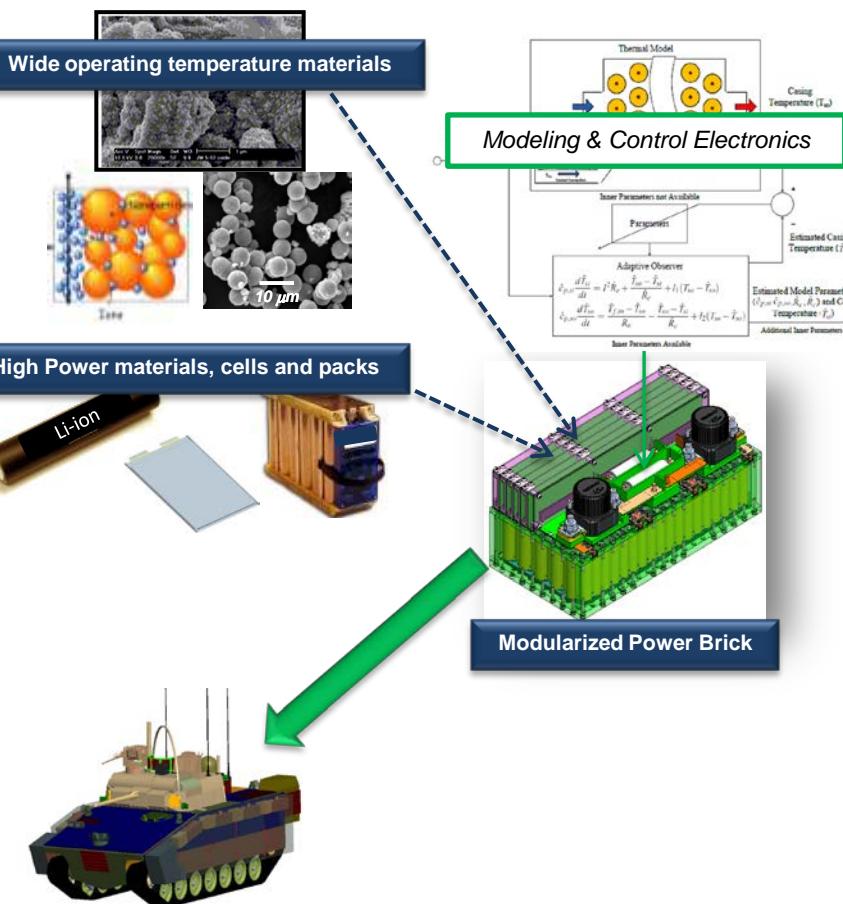
- Gen1 Li-ion 6T batteries developed and under test
- Gen 1 Li-Ion 6T batteries 2x increase in energy density
- Gen 1 Li-Ion 6t batteries cut weight in half (20kg vs. 40kg)





High Voltage (600V) High Power Batteries

Power Brick Battery Technology



Purpose:

- To develop HV battery systems and designs that can meet military shock/vib/environmental requirements.
- To develop compact, modular 600V, high power battery that can be embedded into pulsed power applications to enable multi-use capability.
- To reduce power draw on vehicles for pulse power applications.
- To develop advanced charge control technologies to improve reliability and modularity.

Product:

- Design concepts, standards and specifications for modularized HV batteries for vehicle applications.
- Modularized high power battery systems that can be reconfigured to support multiple high power applications, including advanced survivability, directed energy and non-lethal weapon systems.

Payoff:

- Requirements and as the basis for a standardized high voltage battery systems.
- Key enabler for pulse power applications on military vehicle platforms.
- Significant cost reduction.



High Voltage (600V) High Energy Batteries



COTS Li-Ion Cells



Adapted COTS Li-Ion HV Modules



HE-HMMWV & COTS Li-Ion HV Packs



Standardized Military HV Battery Module & Pack Specifications

Power Brick Battery Technology & Products



Leverage Products, Specs, & Lessons Learned



Purpose:

To develop standardized ground-vehicle high-voltage (HV) battery system & architecture to enable increased commonality as well as reduce overall cost and associated logistics and sustainment burden in support of the Ground Combat Vehicle (GCV) and all other ground-vehicle platforms using high-voltage batteries.

- Develop standardized scalable HV battery modules capable of working in military vehicle environments
- Develop specifications and safety requirements for the HV module and HV battery systems
- Develop and demonstrate prototype HV modules in a HV pack configuration

Product(s):

- High-Voltage battery module and pack system performance specifications
- Interface control documents
- Testing and demonstration of prototype high-voltage standardized, modular battery system
- In-house HV battery testing & qualification capability

Payoff:

- Enabler for silent mobility, hybridization, and export power capabilities
- Reduced logistics and sustainment burden through increased commonality and standardization at the module & pack levels
- Increased cycle life
- Advanced electrical & communication architecture to support connection of vehicle-based high-voltage battery system to external microgrids



Final Mobility Demonstrator Concept Exercise VI

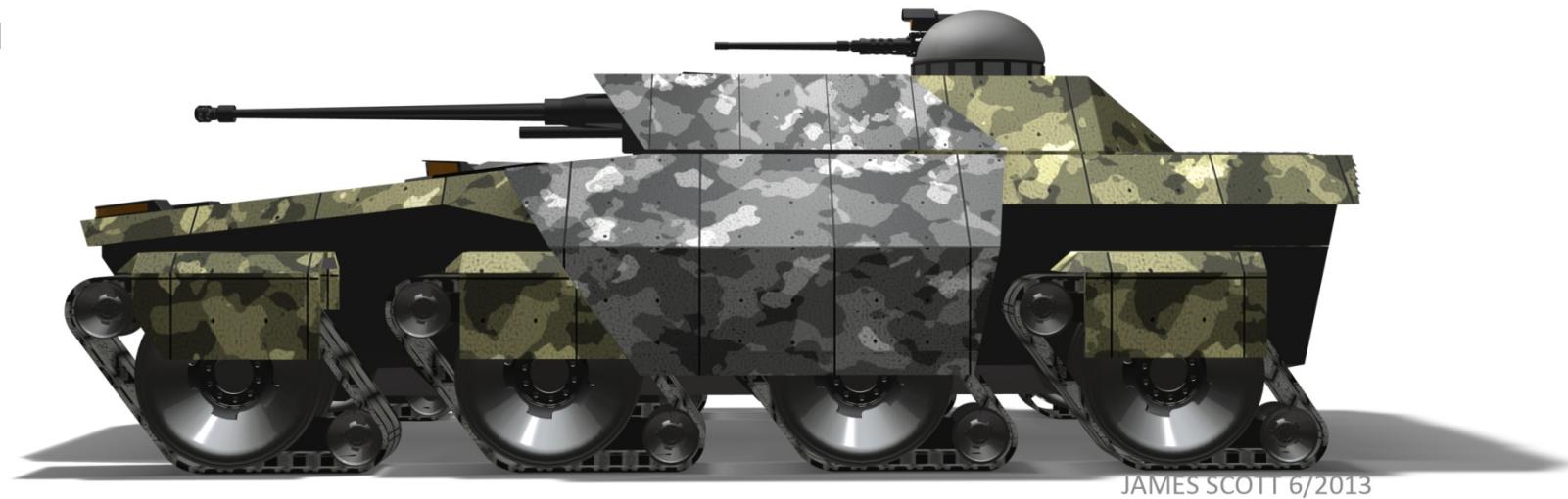




Mobility Demonstrator Concept

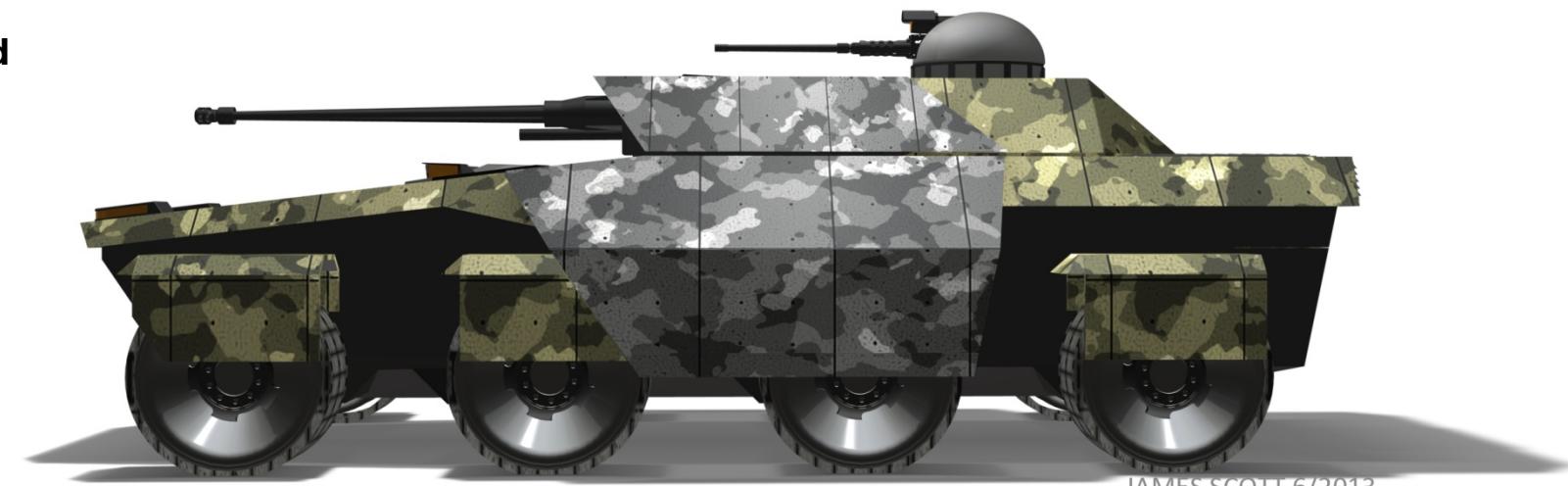


Tracked



JAMES SCOTT 6/2013

Wheeled



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Mobility Demonstrator Concept



Tracked



Wheeled



Mobility Demonstrator Concept



Tracked

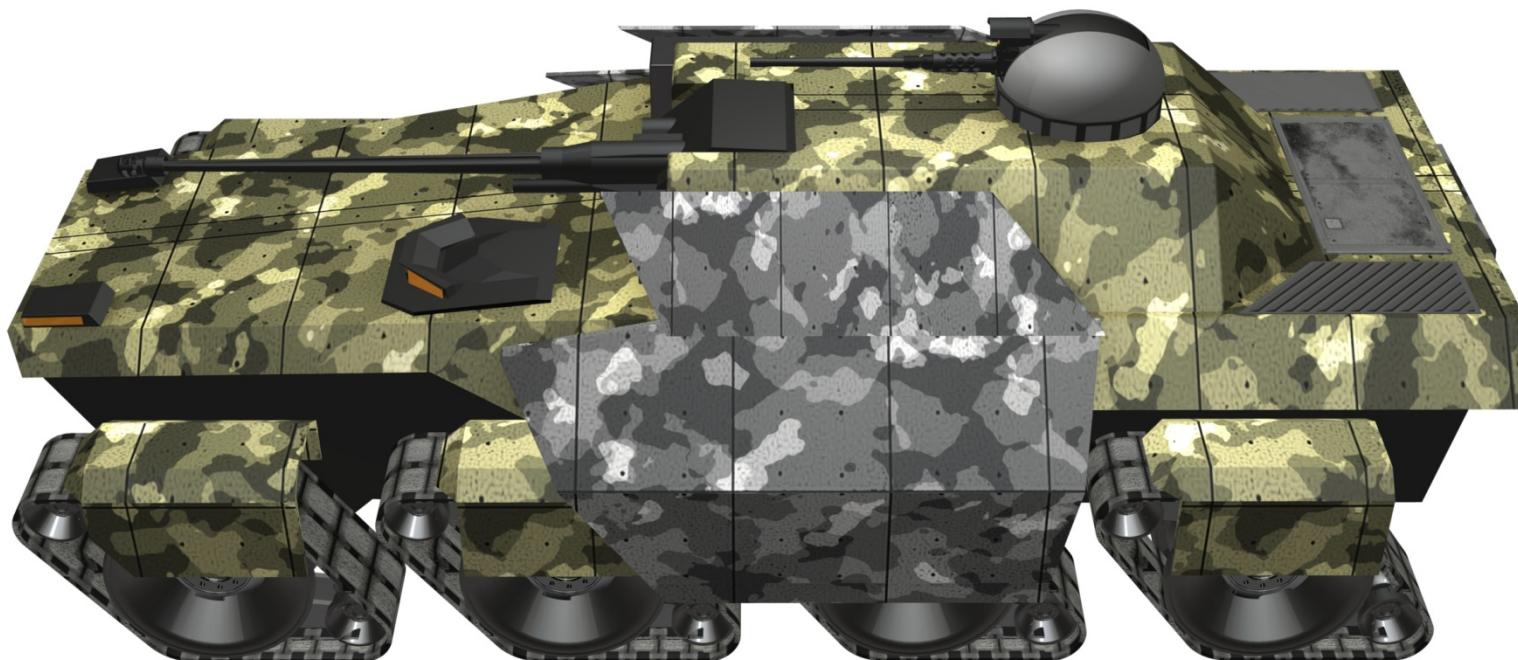


Wheeled





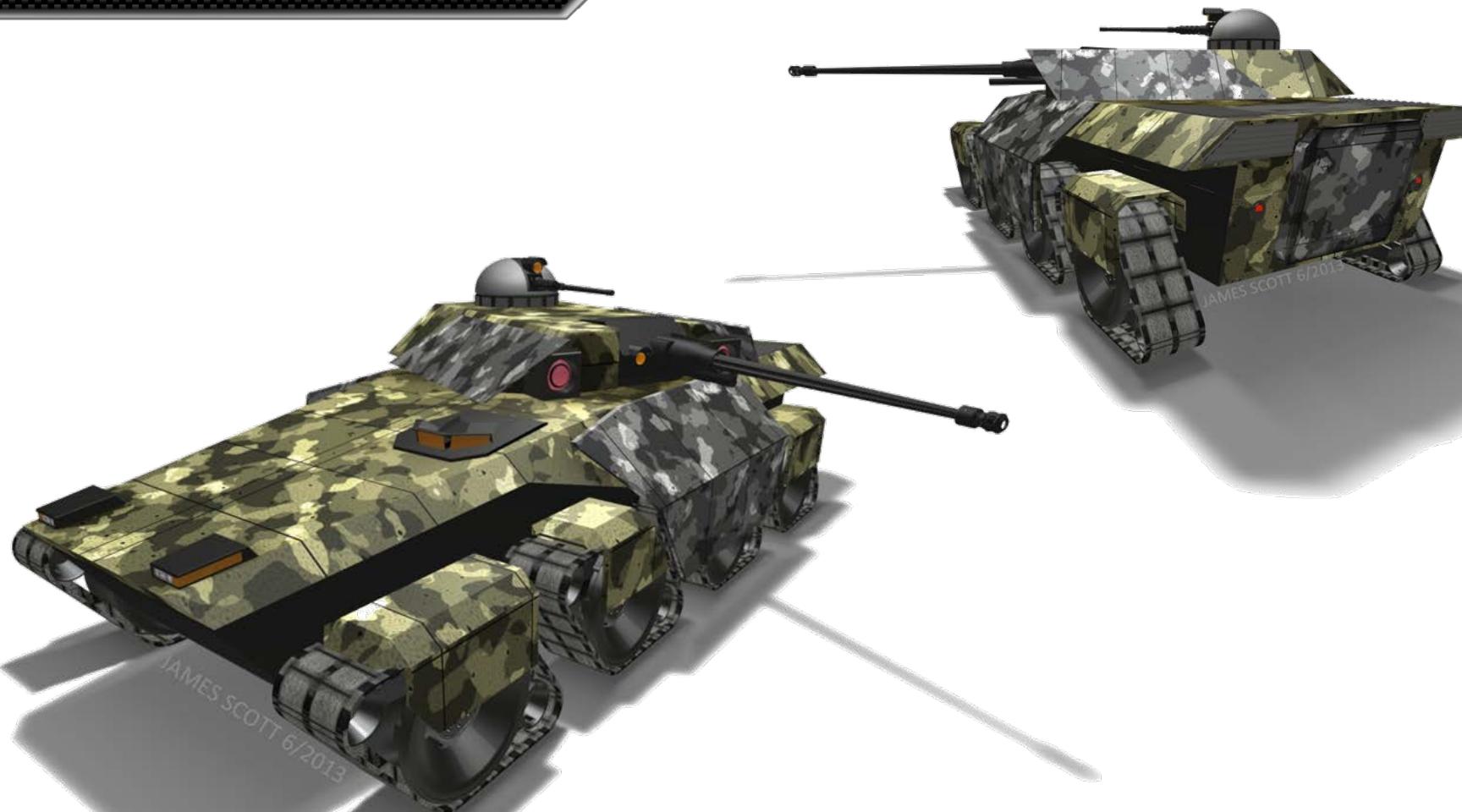
Mobility Demonstrator Concept



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Mobility Demonstrator Concept





Mobility Demonstrator Concept





Mobility Demonstrator Concept





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Conclusion

